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Volume XXV OCTOBER, 1938 Number 4

THE CHARLES RIVER BASIN

PRESIDENTIAL ADDRESS BY ARTHUR D. WESTON,* BOSTON SOCIETY OF CIVIL ENGINEERS, MARCH 16, 1938

ABOUT eight years ago John R. Freeman, past president and eminent member of the Boston Society of Civil Engineers, requested the writer to prepare some of the data available to the Department of Public Health in a manner which would permit a comparison of the present condition of the Charles River Basin with that predicted in the report of the Committee on the Charles River Dam, printed under the provisions of chapter 105 of the Resolves of 1901. In compliance with that request the following facts are presented.

HISTORY OF BASIN

A complete and concise history of the early developments leading to construction of the Charles River Basin is included in the report of the special committee (chapter 105, Resolves of 1901) published in 1903, where mention is made that the construction of the dam was considered as early as 1859. It was not until 1891 that the Honorable Nathan Matthews, then mayor of Boston, recommended that a water park be made of the basin, and that the matter be referred to a state commission. The Charles River Improvement Commission was appointed under the provisions of chapter 390 of the Acts of 1891 for the purpose of considering what improvements could be made in the Charles

---

* Chief Engineer, Massachusetts Department of Public Health, State House, Boston, Mass.

River Basin between the dam at Watertown and the Charles River bridge in Boston. Two reports were submitted by this commission, one under date of February 21, 1892, and the other under date of April 20, 1893, both recommending embankments along the stream in the area under consideration. The recommendations made by this special commission were not acted upon, but in 1893 there was organized a joint board, under the provisions of chapter 475 of the acts of that year. This board, consisting of the Metropolitan Park Commission and the then State Board of Health, investigated the sanitary condition of the Charles River in the lower part of its course, and prepared plans for the improvement of the bed and shores between the Charles River bridge and the Waltham line. Frederic P. Stearns was chief engineer of that board, and his report with that of the board recommended the construction of a dam and lock about 600 feet above the then Craigie bridge. This report was published in the year 1894 as House Document No. 775, and was referred to the Board of Harbor and Land Commissioners with instructions to consider the possible effect of the proposed dam upon shoaling in Boston Harbor. The latter commission was "unable to report in favor of the recommendations contained in the report of the joint board." In spite of these unfavorable recommendations the Legislature, under chapter 531 of the Acts of 1891, authorized and directed the Metropolitan Park Commission to construct and maintain a dam with suitable locks across the river in the vicinity of St. Mary's Street, but no action was taken under this authority.

No further action was taken until 1901, when, under chapter 105 of the Resolves of that year, the Legislature authorized the appointment of a special committee by the Governor to —

> investigate and report upon the feasibility and desirability of constructing and maintaining a dam across Charles River between Boston and Cambridge, in the vicinity of the bridges known as Craigie's Bridge and West Boston Bridge.

Henry S. Pritchett, Samuel M. Mansfield and Richard H. Dana constituted the special committee, and John R. Freeman was appointed chief engineer. The special committee stated in their report in 1903 that —

> There can be no question that a basin of clear water, held at a constant level with attractive banks, is in every way desirable. The questions which your committee feels called to answer are: Can this basin be kept reasonably sweet and clean? Can it be maintained with advantage to the sanitary interests of those who live upon the river banks?

The committee then recommended —

> that a dam be built, sufficiently high to keep out all tides; and that a fresh-water basin be maintained at a permanent level not below grade 8* or above grade 9.* As this basin is to be used for park purposes, it is essential that the condition of the water should not only be harmless to health, but also that there should be no suggestion of sewage; that the water be as pure as reasonably possible and thus both the factor of sanitary safety and the enjoyment of the water park be increased.

Under chapter 465 of the Acts of the year 1903, a special commission, known as the Charles River Basin Commission, was appointed by the Governor with the advice and consent of the Council, to —

> construct across Charles River between the cities of Boston and Cambridge, a dam, at least sufficiently high to hold back all tides and to maintain in the basin above the dam a substantially permanent water level not less than eight feet above Boston base. The dam shall occupy substantially the site of the present Craigie bridge, which shall be removed by the commission. The dam shall be not less than one hundred feet in width at said water level and a part thereof shall be a highway and the remainder shall be a highway, or a park or parkway, as the commission shall determine. The dam shall be furnished with a lock not less than three hundred and fifty feet in length between the gates, forty feet in width and thirteen feet in depth below Boston base, and shall be built with a suitable drawbridge or drawbridges, wasteways and other appliances. The part of the dam used as a highway shall be maintained and operated in the same manner as the Cambridge bridge, and under the laws now or hereafter in force relating to said bridge.

The engineering staff, organized for the purpose of constructing the dam, consisted of Hiram A. Miller, chief engineer; Frederic P. Stearns, consulting engineer; John L. Howard, division engineer in charge of surveys, construction and field work; Frank E. Winsor, division engineer in charge of designing, drafting and office work; and John N. Ferguson, assistant engineer. The dam was essentially completed when the shut-off gates were dropped into place on October 20, 1908. The cost, including all work done by the Charles River Basin Commission in the construction of the dam, locks, drawbridge, marginal conduits, Boston embankment, etc., was about $4,000,000.

Under the provisions of chapter 16 of the Resolves of 1928, a special commission, consisting of the chairman of the Division of Metropolitan Planning and four other persons appointed by the Governor, investigated "means and methods of making the Charles River Basin more safe, suitable and attractive for recreation and civic welfare purposes," and "what means and methods of accomplishing said object were best and most feasible." The following is quoted from the report of that special commission which was printed as House Document No. 1050 of the year 1929:

---

* Boston city base.

> The Charles River Basin is already a water park of great beauty. It now affords health, comfort and enjoyment to thousands of people, but it can be made more beautiful and of greater benefit to the cities and towns of the metropolitan area if the plans presented in this report are carried out. The aim of the Commission has been to make of the Charles River Basin the most beautiful and useful water park in America. To do this boating and canoeing must be made safe, the banks of the river must be shelved to the water's edge, swimming pools and playgrounds must be constructed, boat landings built, parks and parkways constructed, and the basin made a safe and attractive entrance to Boston for thousands who move in and out daily. Thus the basin can be made useful, enjoyable and health-giving to the greatest number of the people of the district.

In their report mention was made of —

> A generous citizen of the Commonwealth who has long loved and admired the Charles River Basin has offered to contribute $1,000,000 to its beautification and improvement.

The commission estimated that to carry their plans into effect would cost $4,250,000. After deducting the $1,000,000 which was to be received as a gift, they planned to pay for the balance of $3,250,000 with $850,000 from the highway fund; $150,000 to be paid by the city of Cambridge as its fair portion of the cost of the underpass of Memorial Drive under Massachusetts Avenue; $150,000 by the city of Boston as its proportion of the cost of the connection between Commonwealth Avenue and St. Paul Street and the riverway; and the balance of $2,100,000 to be assessed upon the thirty-seven cities and towns of the Metropolitan Park District.

These improvements were carried out under the provisions of chapter 371 of the Acts of 1929 by the Metropolitan District Commission. This latter act authorized the commission to —

> (*a*) Widen the Charlesbank park and playground between the dam and the Longfellow bridge by extending the present river boundary westerly by fill to include an additional area which shall have a width not exceeding at any point three hundred feet beyond the present river boundary of said park and playground, so laying out and establishing the new river boundary as not to interfere with the use of said dam or its locks or other appurtenances;
>
> (*b*) Widen the Boston embankment between the Longfellow bridge and Otter Street including the area under the Longfellow bridge by adding thereto, by fill, an area not more than the equivalent of a strip of land two hundred and twenty-five feet

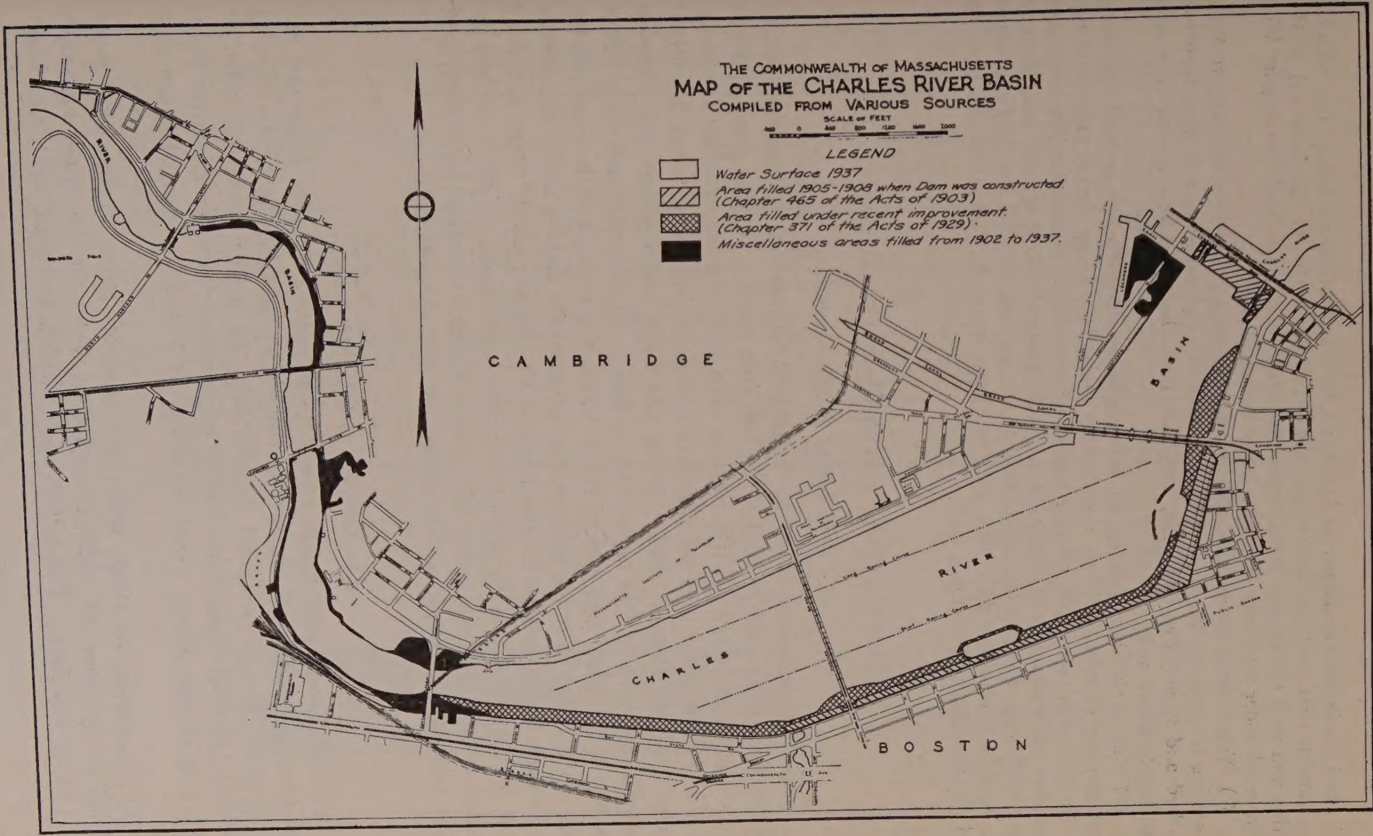

THE COMMONWEALTH OF MASSACHUSETTS
MAP OF THE CHARLES RIVER BASIN
COMPILED FROM VARIOUS SOURCES
SCALE OF FEET
400 0 400 800 1200 1600 2000
LEGEND
Water Surface 1937
Area filled 1905-1908 when Dam was constructed (Chapter 465 of the Acts of 1903)
Area filled under recent improvement. (Chapter 371 of the Acts of 1929).
Miscellaneous areas filled from 1902 to 1937.
CAMBRIDGE
BOSTON
CHARLES
RIVER
BASIN
RIVER
BASIN
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
COMMONWEALTH

FIG. 1.—CHARLES RIVER BASIN, SHOWING FILLED AREAS

wide, laid out in such a manner as to connect by a suitably curved shore line with the Charlesbank park and playground as widened under authority of clause (*a*) of this section and with the Boston embankment between Otter Street and Charlesgate West as widened under authority of clause (*c*) of this section;

(*c*) Widen the Boston embankment between Otter Street and Charlesgate West by adding thereto, by fill, an area not less than the equivalent of a strip of land two hundred and twenty-five feet wide, nor more than the equivalent of a strip of land three hundred feet wide;

(*d*) Extend the shore line, by fill, into the basin along Back Street and Bay State Road between Charlesgate West and Granby Street by adding thereto an area of not less than the equivalent of a strip of land one hundred and twenty-five feet wide, nor more than the equivalent of a strip of land two hundred feet wide, and from Granby Street to Cottage Farm bridge by adding thereto an area not less than the equivalent of a strip of land seventy-five feet wide, nor more than the equivalent of a strip of land one hundred and fifty feet wide.

The Charles River Dam and Basin

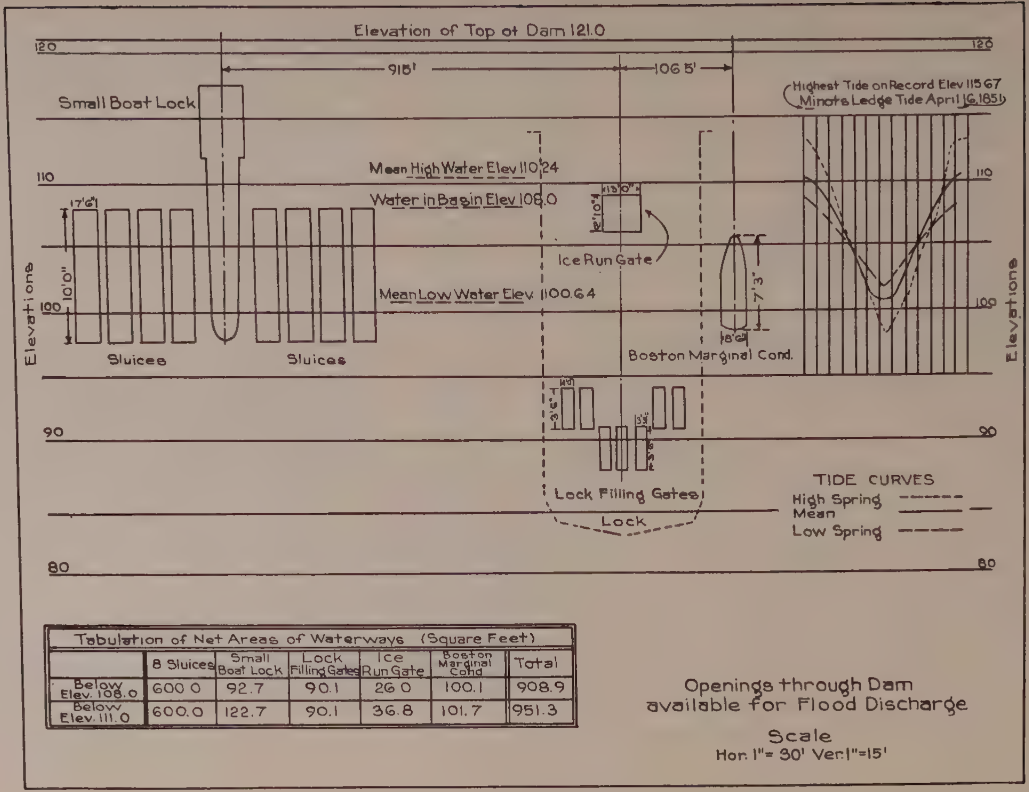
The Charles River Dam

The dam consists of earth fill inside of masonry retaining walls, is 1,200 feet long and from 100 to 500 feet wide. In this dam there is a lock for large boats on the Boston side and one for smaller boats on the Cambridge side. There also are openings for the Boston Marginal Conduit on the Boston side. There are eight sluice gates, the bottom of which is about 10 feet below the surface. These gates are each 7 feet 6 inches by 10 feet, and one of them has a connection with a salt-water sluice 5 by 5 feet in cross section, the invert of which is 26½ feet below the surface of the water in the basin. In the ship lock there are four upper lock gates 4 feet by 3 feet 6 inches, and three 3 feet 3 inches by 3 feet 6 inches, and six lower lock gates 3 feet 10 inches by 9 feet, and an ice run gate through which water can be released.

The Charles River Basin

The Charles River Basin is approximately 8½ miles long and extends from the dam near the site of the old Craigie bridge to the dam at Watertown. It was designed to maintain the water above the dam at elevation 108.0 Metropolitan District Commission Sewer Division base, which is 2.38 feet above mean sea level, or 8.03 feet above Boston city base.

As completed in 1908, when the shut-off gates in the dam were dropped on October 20, 1908, it varied in width in the upper six miles from 150 to 400 feet. The lower basin, which is about 2½ miles long,


Elevation of Top of Dam 121.0
120
120
91.5'
106 5'
Small Boat Lock
Highest Tide on Record Elev 115 67
Minots Ledge Tide April 16, 1851
Mean High Water Elev 110.24
Water in Basin Elev 108.0
Mean Low Water Elev 100.64
110
110
100
100
Elevations
Elevations
17'6"
10'0"
Sluices
Sluices
13'0"
12'10"
Ice Run Gate
7'3"
8'6"
Boston Marginal Cond.
3'6"
3'3"
5'6"
90
90
Lock Filling Gates
Lock
TIDE CURVES
High Spring
Mean
Low Spring
80
80
Openings through Dam available for Flood Discharge
Scale
Hor. 1" = 30' Ver. 1" = 15'

Tabulation of Net Areas of Waterways (Square Feet)

	8 Sluices	Small Boat Lock	Lock Filling Gates	Ice Run Gate	Boston Marginal Cond	Total
Below Elev. 108.0	600 0	92.7	90.1	26 0	100.1	908.9
Below Elev. 111.0	600.0	122.7	90.1	36.8	101.7	951.3

FIG. 2. — OPENINGS THROUGH CHARLES RIVER DAM FOR FLOOD DISCHARGE

had a maximum width of 2,300 feet. The basin varied in average depth from 15 feet at the lower end to 3 feet at the upper, the maximum depth being 30 feet.

Unfortunately, until recently only very meager information has been available concerning the area and capacity of the basin. No survey by the Metropolitan District Commission as to the actual area and capacity of the basin has been made since the dam was constructed.

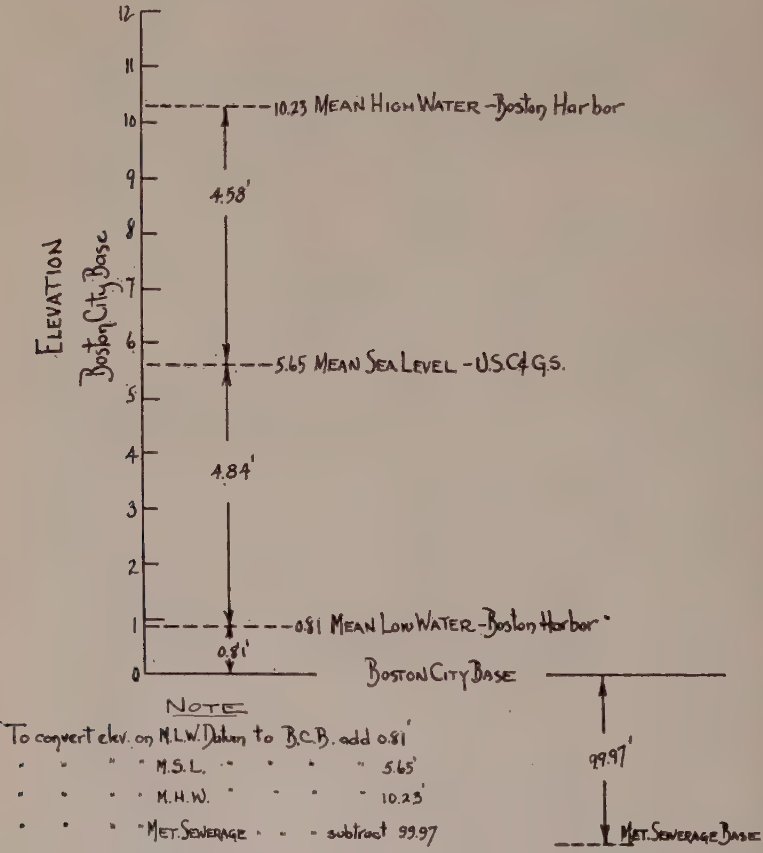

12
11
10
9
8
7
6
5
4
3
2
1
0
ELEVATION
Boston City Base
10.23 MEAN HIGH WATER - Boston Harbor
4.58'
5.65 MEAN SEA LEVEL - U.S.C.&G.S.
4.84'
0.81 MEAN LOW WATER - Boston Harbor
0.81'
BOSTON CITY BASE
99.97'
MET. SEWERAGE BASE
NOTE
To convert elev. on M.L.W. Datum to B.C.B. add 0.81'
" " " " M.S.L. " " " " 5.65'
" " " " M.H.W. " " " " 10.23'
" " " " MET. SEWERAGE " " " subtract 99.97

FIG. 3. — RELATION OF VARIOUS TIDAL DATA TO BOSTON CITY BASE

The report of the Joint Board on the Improvement of the Charles River, published in 1895, stated that a dam located about 600 feet upstream from Craigie bridge would create a basin of 758 acres with a capacity of 3,300,000,000 gallons at grade 8,* Boston city base. John R. Freeman, in his report in 1903, stated that the proposed basin with a dam at Craigie bridge would contain 3,435,000,000 gallons. It was estimated that the dam constructed at this point would increase the area to about 776 acres, but in 1929, when various studies were made to determine the probable effect of flood flows in the river on the elevation of water in the basin, if further filling were carried out along the Boston Esplanade between the dam and Cottage Farm bridge, as proposed, it was estimated that the area of the basin before filling commenced was 750 acres, and that the capacity was 3,458,000,000 gallons. The recent improvements along the Boston side are said to have decreased the area 44 acres, and it was estimated by the Metropolitan District Commission that from dredging and filling the capacity has been decreased about 42,000,000 gallons, and that the present basin has an area of about 706 acres and a capacity of about 3,416,000,000 gallons.

During the year 1938 a survey was made by the Federal Works Progress Administration (Pollution Project W. P., 16082) under the sponsorship of the Department of Public Health, which has resulted in plans showing the depth of the basin throughout its entire length. The following table, showing the area and capacity of the Charles River Basin, is arranged from data shown on those plans:

TABLE 1. — AREA AND CAPACITY OF CHARLES RIVER BASIN

DEPTH BELOW NORMAL ELEVATION OF BASIN †	Area (Acres)	Capacity (Million Gallons)
—	696.27	3,348.75
5	594.94	2,297.00
10	473.78	1,426.47
15	322.10	778.16
20	180.47	368.78
25	85.19	152.37
30	38.65	52.18
35	12.34	10.63
40	0.71	—

---

* See Fig. 3 for relation of various data.

† Normal elevation of the basin is grade 8.0 Boston city base, or elevation 2.35 mean sea level datum.

Conclusions of Special Committee (Chapter 105, Resolves of 1901)

The special committee, appointed under chapter 105 of the Resolves of 1901, concluded that —

> A comparatively still body of fresh water with animal and plant growths will dispose of a considerable amount of sewage admitted from time to time, and will tend to purify itself even if no more fresh water is added.
>
> . . . Although the amount of fresh water coming over and through the Watertown dam . . . seldom averages less than 70 cubic feet per second for the 24 hours in dry seasons, there is good reason to believe that this is sometimes reduced to 30 cubic feet a second, for a month at a time, by storage in mill ponds while turbines are shut down.
>
> Notwithstanding the amount of sewage that enters the basin even at present, . . . equivalent to the constant discharge by a population of from 5,000 to 8,000 people, . . . it is the unanimous opinion of the engineers and experts of the committee that a fresh water basin . . . would not affect injuriously the health of the inhabitants in the neighborhood.
>
> Malaria is only spread . . . by means of the Anopheles mosquito. This mosquito breeds only in small pools of fresh or partially salt water. . . . There are now . . . many breeding places of this mosquito on the borders of and near Charles River. . . .
>
> The level of the ground water in the Back Bay would not be raised; . . . the ground water level . . . seems to be chiefly controlled by leakage into sewers.
>
> The combined sewers flowing from the Back Bay and from certain of the lower parts of Cambridge in case of heavy rains during high tide, back up into and overflow the cellars. . . . If a permanent grade of 8 or 9 were maintained in the basin, this nuisance and danger to health would be removed.
>
> In the main basin the appearance during storm overflows is often worse than the reality, as the turbid fresh water floats over the salt in rather thin layers. If the basin were fresh, that condition would not exist. . . .
>
> With the introduction of the new high level sewer . . . on the Boston side . . . the amount of sewage entering the basin will be much less than at present.
>
> . . . benefit rather than harm will come to the harbor from the erection of the dam, and that, should any shoaling occur, it will be small and of light material and can easily be removed. . . .
>
> . . . traffic on the Charles River . . . should be preserved.
>
> The construction of a dam with a proper system of locks . . . will . . . rather facilitate . . . than hinder this traffic. The formation of ice in the winter will be a possible objection. . . .

Freeman in his report, published with the report of the special committee, also indicated the following advantages and disadvantages of building the proposed dam and maintaining a basin:

Advantages	*Disadvantages*
1. . . . magnificent opportunity at comparatively small expense for replacing unsightly tidal mud flats and unclean muddy shores . . . by a great water park. . . .	1. The extra cost (if any) of the dam and its auxiliary structure above the cost of the structures that will be required for sanitary and other reasons. . . .
2. . . . probable large increase in valuation of the marginal lands. . . .	2. The loss of interest involved in an earlier expenditure for the separation of sewage from storm water. . . .
3. . . . lessened expense for development of . . . park lands upon the margin of Charles River. . . .	3. . . . interference to navigation by ice. . . .
4. . . . *improved sanitary conditions* . . . by lowering the extreme flood level in the present sewer and storm-water drains. . . .	4. The compensation or damages . . . for those owning wharfs.
5. . . . will prevent the uncovering of large areas of foul smelling and unsightly mud flats. . . .	5. . . . increase in the cost of dredging. . . .
6. . . . lessening of the probability of malaria and a lessening of the mosquito pest. . . .	6. . . . small increase in total amount . . . at . . . stations of the Boston main drainage and the metropolitan sewerage. . . .
7. . . . prevent the flooding of . . . marsh land in Brighton, Watertown and Newton. . . .	7. The need and cost of flushing Broad and Lechmere canals.
8. . . . constant water level . . . will give improved conditions for navigation. . . .	8. The need and cost of special means for circulation in the Fens Basin. . . .
9. . . . will permit a form of dock wall construction that will be more economical for the improvement of shipping facilities. . . .	
10. There will be some gain in economy of power because of the cheap and generous supply of fresh water for steam and condensation made available to the electric stations and other steam plants. . . .	
11. . . . cost of the dam, together with . . . auxiliary structures . . . will be far less than the expense of removal of . . . mud flats by dredging, the filling of guzzles and other depressions . . . and the extra cost of protecting the shores by embankment walls, bulkheads, . . . etc.	

Increase in Valuation of Marginal Lands

The writer has attempted, but abandoned, an estimate of the probable increase in valuation of the marginal lands along the Charles River Basin because of the many complications involved. For example, much land privately owned prior to the construction of the basin has been acquired for park purposes, while much additional land acquired by Harvard University and the Massachusetts Institute of Technology is exempt from taxation. In addition, much privately owned property has recently suffered depreciation in valuation which is in no way related to the existence of the basin, and the valuation of many properties in the vicinity of the basin, like those remote, has increased since the completion of the basin, in 1908, for reasons in no way connected with the establishment of the basin. There can be no doubt, however, in the mind of any one but that the vicinity of the basin since the construction of the dam is a more desirable place to reside, and that the present basin is not only beautiful, but of great value for recreational purposes.

Flow of Charles River

The subject which received the most consideration in the discussions of Stearns and Freeman was the probable flow entering the basin both during floods and droughts. This is to be expected, as of course the flood flows must be cared for without damage to property, and the flow during periods of drought might have a serious effect upon the sanitary condition of the water in the basin.

Dry Weather Flow

While the natural drainage area, according to the topographical maps, above the Charles River Basin comprises about 270 square miles, the effective drainage area is considerably less than this amount, owing to the run-off from 66.2 square miles, or 24 per cent of the total drainage area, being diverted through a man-made canal and Mother Brook in Dedham to an outlet in the Neponset River at Hyde Park in accordance with an agreement made in 1831 between the proprietors of the mills on Mother Brook and the Neponset River and those on the Charles River. Also in the municipalities of Waltham, Weston and Lincoln there are about 23.6 square miles of this drainage area which are set aside for water-supply purposes for the city of Cambridge, and from which, except in flood periods, practically no water reaches the Charles River. In addition, a considerable amount of water is diverted through sewerage systems to points outside of the drainage area by leakage and in the ordinary uses of water for domestic and manufacturing purposes. There are also losses due to evaporation on meadow lands.

The following table, prepared by the writer in his report to the joint board, published as House Document No. 158 of the Massachusetts Legislature of 1932, shows the average daily diversions from the Charles River between Charles River Village and Watertown dam in the year 1930:

Table 2. — Diversions from Charles River between Charles River Village and Watertown Dam (Gallons per Day)

Location	Diversion for Water Consumption Purposes, 1930	Estimated Leakage or Infiltration into Sewerage Systems	Estimated Evaporation Losses or Absorbed by Meadows	Manufacturing Wastes Discharged to Sewers	Total Estimated Losses
Charles River Village to Mother Brook:					
Needham	651,000	–	–	–	–
Dedham	1,097,000	–	–	–	–
Total	1,748,000	716,000	680,000	–	3,144,000
Mother Brook to Newton Upper Falls:					
Brookline	4,385,000	–	–	–	–
Newton	4,572,000	–	–	–	–
Total	8,957,000	660,000	2,371,000	115,000	12,103,000
Newton Upper Falls to Newton Lower Falls:					
Wellesley	938,000	–	–	–	–
Total	938,000	80,000	194,000	–	1,212,000
Newton Lower Falls to Boston Manufacturing Company dam:					
Waltham	2,253,000	–	–	–	–
Total	2,253,000	2,365,000	1,069,000	90,000	5,777,000
Boston Manufacturing Company dam to Watertown dam	–	1,700,000	213,000	20,000	1,933,000
Grand total	13,896,000	5,521,000	4,527,000	225,000	24,169,000

The following table shows the amount of water diverted and wasted from Stony Brook drainage area for the years 1931 to 1937, inclusive:

TABLE 3. — CHARLES RIVER — WATER DIVERTED FROM THE WATERSHED AND WASTAGE FROM STONY BROOK RESERVOIR, 1931–1937 (MILLION GALLONS)

YEAR AND MONTH	To Cities and Towns* (1)	To Mother Brook (2)	Total, Columns (1) and (2)	Wastage from Stony Brook Reservoir
1931				
January	430.0	1,130.0	1,560.0	–
February	408.4	1,733.6	2,142.0	–
March	412.6	4,688.3	5,100.9	927.1
April	425.5	3,490.0	3,915.5	421.5
May	450.0	2,604.6	3,054.6	97.8
June	429.0	4,556.4	4,985.4	421.6
July	442.1	1,556.7	1,998.8	2.8
August	429.8	725.3	1,155.1	–
September	421.2	480.8	902.0	–
October	438.6	280.5	719.1	–
November	418.6	288.9	707.5	–
December	431.5	607.2	1,038.7	–
Total	5,137.3	22,142.3	27,279.6	1,870.8
1932				
January	431.9	1,881.3	2,313.2	138.6
February	408.7	1,461.9	1,870.6	27.3
March	442.8	2,424.3	2,867.1	351.4
April	434.4	3,276.7	3,711.1	350.4
May	473.5	1,105.9	1,579.4	7.6
June	461.7	445.9	907.6	1.4
July	472.2	212.4	684.6	4.1
August	446.0	196.7	642.7	–
September	416.7	990.8	1,407.5	0.4
October	446.0	1,894.9	2,340.9	231.2
November	423.0	4,171.0	4,594.0	798.9
December	427.6	1,670.6	2,098.2	173.1
Total	5,284.5	19,732.4	25,016.9	2,084.4
1933				
January	417.0	1,987.3	2,404.3	153.5
February	351.6	1,796.0	2,147.6	383.1
March	441.8	5,355.0	5,796.8	1,780.4

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* Wellesley, Needham, Dedham, Brookline, Newton and Waltham.

TABLE 3. — CHARLES RIVER — WATER DIVERTED FROM THE WATERSHED AND WASTAGE FROM STONY BROOK RESERVOIR, 1931–1937 (MILLION GALLONS) — *Continued*

YEAR AND MONTH	To Cities and Towns (1)	To Mother Brook (2)	Total, Columns (1) and (2)	Wastage from Stony Brook Reservoir
1933 — Con.				
April	419.6	6,387.6	6,807.2	2,027.1
May	461.1	2,186.3	2,647.4	112.2
June	452.9	762.0	1,214.9	–
July	472.1	369.3	841.4	–
August	447.5	191.0	638.5	–
September	423.0	1,814.2	2,237.2	273.7
October	443.2	1,233.1	1,676.3	–
November	422.0	815.6	1,237.6	69.4
December	429.9	1,239.5	1,669.4	–
Total	5,181.7	24,136.9	29,318.6	4,799.4
1934				
January	418.4	3,212.0	3,630.4	640.6
February	428.0	877.0	1,305.0	51.1
March	471.4	4,409.5	4,880.9	891.6
April	440.8	4,699.7	5,140.5	1,281.4
May	477.2	2,413.2	2,890.4	579.1
June	470.6	920.9	1,391.5	38.9
July	547.3	298.7	846.0	–
August	453.8	188.6	642.4	–
September	440.8	328.7	769.5	–
October	446.0	610.3	1,056.3	–
November	425.3	691.5	1,116.8	–
December	444.6	1,654.5	2,099.1	–
Total	5,464.2	20,304.6	25,768.8	3,482.7
1935				
January	444.4	3,174.5	3,618.9	218.4
February	402.9	2,121.7	2,524.6	239.4
March	439.6	5,118.5	5,558.1	930.3
April	424.9	5,017.7	5,442.6	1,169.5
May	489.6	1,213.2	1,702.8	313.2
June	439.9	1,233.7	1,673.6	178.4
July	483.6	405.7	889.3	5.4
August	530.5	179.8	710.3	–

TABLE 3. — CHARLES RIVER — WATER DIVERTED FROM THE WATERSHED AND WASTAGE FROM STONY BROOK RESERVOIR, 1931–1937 (MILLION GALLONS) — *Concluded*

YEAR AND MONTH	To Cities and Towns (1)	To Mother Brook (2)	Total, Columns (1) and (2)	Wastage from Stony Brook Reservoir
1935 — Con.				
September	422.5	304.1	726.6	–
October	459.6	115.9	575.5	–
November	425.8	452.8	878.6	–
December	438.5	716.1	1,154.6	–
Total	5,401.8	20,053.7	25,455.5	3,054.6
1936				
January	439.8	2,020.8	2,460.6	–
February	426.6	1,213.7	1,640.3	0.9
March	454.6	9,811.1	10,265.7	897.4
April	427.0	4,911.0	5,338.0	966.4
May	491.1	1,619.6	2,110.7	197.1
June	502.6	449.8	952.4	–
July	507.8	183.4	691.2	–
August	462.9	118.7	581.6	–
September	430.4	1,120.6	1,551.0	–
October	456.9	1,067.6	1,524.5	–
November	440.7	729.0	1,169.7	–
December	443.0	4,669.3	5,112.3	223.1
Total	5,483.4	27,914.6	33,398.0	2,284.9
1937				
January	432.7	3,984.3	4,417.0	383.3
February	386.2	2,791.9	3,178.1	174.7
March	438.2	3,153.8	3,592.0	301.3
April	419.6	2,912.7	3,332.3	378.0
May	454.5	2,674.9	3,129.4	258.1
June	443.1	1,330.0	1,773.1	56.7
July	500.1	442.3	942.4	18.8
August	480.3	291.2	771.5	–
September	422.7	743.2	1,165.9	–
October	438.8	570.7	1,009.5	–
November	420.3	1,522.0	1,942.3	10.9
December	436.1	3,785.2	4,221.3	201.5
Total	5,272.6	24,202.2	29,474.8	1,784.3

A continuous record of the flow of the Charles River at Charles River Village has been maintained by the Department of Public Health since the year 1913. In addition, observations of the flow have been made quite frequently since the year 1900 at Ames Street bridge in Dedham, under the direction of the Commissioner for the Proprietors of Mills, of Mill Brook, or Mother Brook, and Neponset River, provision for such a commissioner having been made by chapter 161 of the Acts of 1900. These measurements are used by the commissioner to estimate the flow of the Charles River at Newton Upper Falls and the flow through Mother Brook.

Records of the rainfall in the Charles River Valley watershed have been compiled at a number of stations for a great many years, the longest record being that of the Boston Manufacturing Company at Waltham, which covers the period 1825 to 1929. An examination of these records shows that, with the exception of the year 1846, the rainfall during the year 1930 was one of the lowest of record in this valley. The low rainfall, together with the great deficiency for the last six months of 1929, reduced the flow of the Charles River above the dam at Watertown to what is believed to have been the lowest of which there is record. Estimates of the yield of this river, based on the measurements of the flow per square mile above the gaging station of the Department of Public Health at Charles River Village for the year 1930, have been made for the drainage area above the Watertown dam, the dam at the Boston Manufacturing Company at Waltham, the river at the entrance to the mill pond of the Boston Manufacturing Company and above Mother Brook. These results are shown in the following table:

TABLE 4. — NET YIELD OF CHARLES RIVER, BASED ON YIELD CONDITION OF 1930

LOCATION	Based on Yield of Charles River at Charles River Village (Million Gallons Daily) *
Above Mother Brook	21.00
Above Newton Lower Falls	2.21
Above Boston Manufacturing Company dam	4.60
Above Watertown dam	6.16

* Utilizing existing pondage.

For a number of years estimates of flow were made by the Boston Manufacturing Company at Waltham from gage heights on the dam and head on wheels at their plant; these records covered the period from 1899 to 1911, inclusive.

The following table, prepared by George V. White, assistant engineer, Massachusetts Department of Public Health, shows the flow by weeks in the Charles River at the gaging station below the Boston Manufacturing Company in Waltham since this station was first established, in August, 1931:

Table 5. — Average Weekly Measured Flow in Cubic Feet per Second at the United States Geological Survey Gaging Station just below the Boston Manufacturing Company's Dam at Waltham

[Drainage area may be considered as 225 square miles]

Week Ending —	Cubic Feet per Second	Week Ending —	Cubic Feet per Second
1931		1932 — Con.	
Aug. 9	43	Feb. 7	212
16	117	14	217
23	153	21	219
30	101	28	175
Sept. 6	117	Mar. 6	207
13	79	13	391
20	44	20	347
27	57	27	264
Oct. 4	41	Apr. 3	583
11	32	10	590
18	30	17	495
25	39	24	430
Nov. 1	48	May 1	263
8	57	8	228
15	34	15	141
22	32	22	129
29	32	29	63
Dec. 6	40	June 5	74
13	77	12	40
20	80	19	47
27	78	26	73
		July 3	44
1932		10	47
Jan. 3	109	17	41
10	218	24	27
17	247	31	21
24	290	Aug. 7	18
31	280	14	19

TABLE 5. — AVERAGE WEEKLY MEASURED FLOW IN CUBIC FEET PER SECOND AT THE UNITED STATES GEOLOGICAL SURVEY GAGING STATION JUST BELOW THE BOSTON MANUFACTURING COMPANY'S DAM AT WALTHAM — *Continued*

WEEK ENDING —	Cubic Feet per Second	WEEK ENDING —	Cubic Feet per Second
1932 — Con.		1933 — Con.	
Aug. 21	24	May 7	616
28	27	14	399
Sept. 4	26	21	253
11	44	28	188
18	50	June 4	169
25	244	11	140
Oct. 2	214	18	88
9	116	25	86
16	43	July 2	70
23	348	9	48
30	542	16	50
Nov. 6	471	23	70
13	722	30	37
20	840	Aug. 6	27
27	554	13	25
Dec. 4	391	20	15
11	264	27	6
18	171	Sept. 3	40
25	226	10	74
		17	137
1933		24	610
Jan. 1	295	Oct. 1	416
8	286	8	163
15	312	15	196
22	303	22	158
29	316	29	143
Feb. 5	264	Nov. 5	142
12	223	12	125
19	266	19	123
26	399	26	114
Mar. 5	515	Dec. 3	102
12	811	10	118
19	723	17	114
26	988	24	184
Apr. 2	878	31	225
9	925		
16	1,050	1934	
23	1,330	Jan. 7	239
30	947	14	534

TABLE 5. — AVERAGE WEEKLY MEASURED FLOW IN CUBIC FEET PER SECOND AT THE UNITED STATES GEOLOGICAL SURVEY GAGING STATION JUST BELOW THE BOSTON MANUFACTURING COMPANY'S DAM AT WALTHAM — *Continued*

WEEK ENDING —	Cubic Feet per Second	WEEK ENDING —	Cubic Feet per Second
1934 — Con.		1934 — Con.	
Jan. 21	535	Oct. 21	180
28	462	28	106
Feb. 4	339	Nov. 4	123
11	163	11	145
18	140	18	161
25	113	25	139
Mar. 4	159	Dec. 2	128
11	919	9	257
18	797	16	167
25	653	23	177
Apr. 1	682	30	265
8	852		
15	729	1935	
22	796	Jan. 6	159
29	702	13	477
May 6	557	20	692
13	491	27	457
20	364	Feb. 3	330
27	226	10	292
June 3	155	17	271
10	106	24	424
17	123	Mar. 3	546
24	165	10	745
July 1	121	17	941
8	71	24	811
15	66	31	591
22	33	Apr. 7	482
29	22	14	731
Aug. 5	42	21	1,197
12	41	28	822
19	23	May 5	519
26	7.6	12	418
Sept. 2	21	19	453
9	27	26	297
16	40	June 2	165
23	48	9	195
30	100	16	308
Oct. 7	160	23	397
14	153	30	329

TABLE 5. — AVERAGE WEEKLY MEASURED FLOW IN CUBIC FEET PER SECOND AT THE UNITED STATES GEOLOGICAL SURVEY GAGING STATION JUST BELOW THE BOSTON MANUFACTURING COMPANY'S DAM AT WALTHAM — *Continued*

WEEK ENDING —	Cubic Feet per Second
1935 — Con.	
July 7	158
14	139
21	43
28	114
Aug. 4	42
11	38
18	46
25	94
Sept. 1	36
8	62
15	102
22	46
29	32
Oct. 6	29
13	33
20	26
27	22
Nov. 3	23
10	21
17	4.9
24	61
Dec. 1	115
8	162
15	43
22	137
29	61
1936	
Jan. 5	75
12	243
19	353
26	358
Feb. 2	285
9	156
16	118
23	221
Mar. 1	232
8	219
15	1,174
1936 — Con.	
Mar. 22	2,249
29	1,777
Apr. 5	1,117
12	923
19	813
26	596
May 3	417
10	380
17	324
24	185
31	70
June 7	111
14	63
21	65
28	75
July 5	82
12	38
19	45
26	26
Aug. 2	12
9	8
16	9
23	28
30	38
Sept. 6	131
13	65
20	150
27	254
Oct. 4	230
11	162
18	116
25	157
Nov. 1	124
8	122
15	150
22	118
29	95
Dec. 6	142
13	365

TABLE 5.—AVERAGE WEEKLY MEASURED FLOW IN CUBIC FEET PER SECOND AT THE UNITED STATES GEOLOGICAL SURVEY GAGING STATION JUST BELOW THE BOSTON MANUFACTURING COMPANY'S DAM AT WALTHAM—*Concluded*

WEEK ENDING—	Cubic Feet per Second
1936—Con.	
Dec. 20	753
27	892
1937	
Jan. 3	674
10	560
17	483
24	496
31	593
Feb. 7	474
14	364
21	383
28	446
Mar. 7	393
14	276
21	497
28	627
Apr. 4	456
11	380
18	432
25	418
May 2	568
9	509
16	371
23	372
30	352
June 6	284
13	208
1937—Con.	
June 20	180
27	196
July 4	160
11	93
18	69
25	57
Aug. 1	39
8	28
15	37
22	30
29	104
Sept. 5	115
12	138
19	134
26	87
Oct. 3	55
10	91
17	46
24	45
31	160
Nov. 7	189
14	119
21	247
28	268
Dec. 5	442
12	639
19	477
26	434

The following diagrams (Figs. 4 and 5) show a comparison of this flow with the measured flows of the Connecticut River and Swift River during the same periods of time:

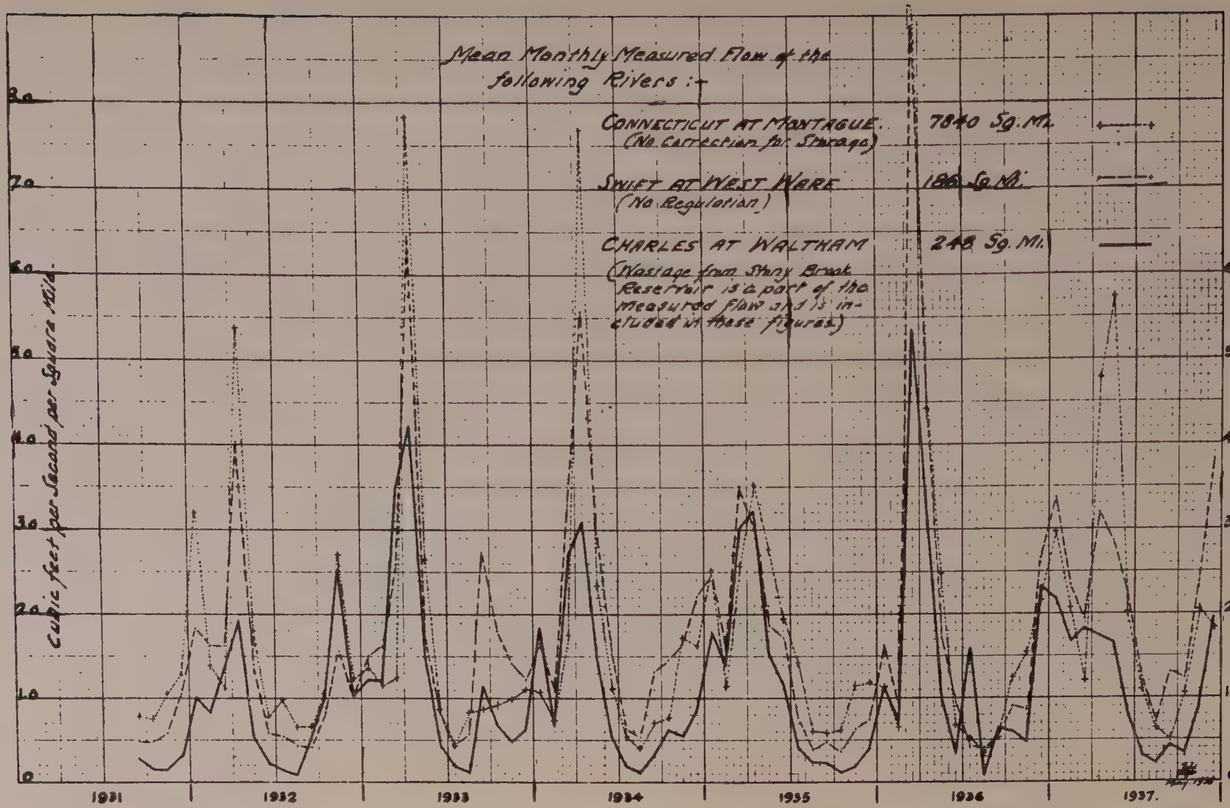

FIG. 4. — COMPARISON OF FLOW OF CHARLES RIVER WITH MEASURED FLOW OF CONNECTICUT AND SWIFT RIVERS

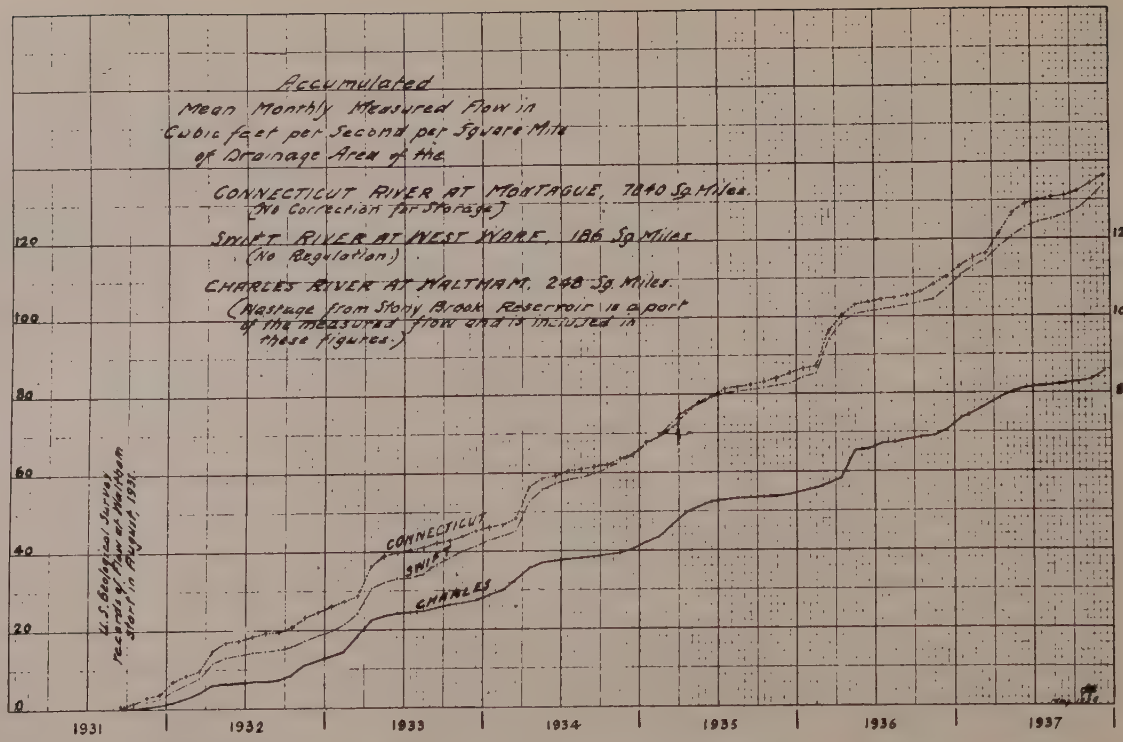

FIG. 5. — COMPARISON OF FLOW OF CHARLES RIVER WITH MEASURED FLOW OF CONNECTICUT AND SWIFT RIVERS

An examination of Table 5 will show that during the summer months the flow in the Charles River entering the basin for a week at a time may not exceed 5.0 cubic feet per second, or 3.23 million gallons in twenty-four hours, compared to 8 to 10 cubic feet per second estimated by Freeman to be the minimum flow. When it is considered that below the point where the measurements were made the river flows a distance of 2.6 miles before it enters the Charles River Basin, and that the flow is subject to additional losses, something further must be done to conserve the flow of this stream by acquiring water rights in addition to those acquired by the Metropolitan District Commission at the Boston Manufacturing Company, or by the construction of storage reservoirs, if sanitary conditions in the Charles River Basin are to be maintained. Under present conditions of low flow in the river it is necessary to introduce tidewater at times to maintain the water in the basin at a proper elevation.

Under existing legislation the taking of water for water-supply purposes from within the Charles River Valley is limited, in the case of the Dedham Water Company, under chapter 138 of the Acts of 1876, to 1,500,000 gallons per day; in connection with the city of Newton, under chapter 683 of the Acts of 1913, to 8,000,000 gallons per day; and in the case of the town of Brookline, to 8,000,000 gallons per day, under chapter 684 of the Acts of 1913. The taking of water by these latter municipalities is subject to approval by the State Department of Public Health. There is also a limitation to the amount of water which can be taken by Needham, under chapter 107 of the Acts of 1888, to 500,000 gallons per day, and by Waltham, under chapter 226 of the Acts of 1909, to 5,000,000 gallons per day. There is some question as to the limitation under these acts of water taken from the ground near the river. In the cases of Newton and Brookline the actual quantities used during dry periods may be reduced by restrictions which may be imposed by the State Department of Health.

The following table shows the average daily water consumption during the past five years of the above-named municipalities; also the water consumption of Cambridge, which takes water from Stony Brook, a tributary of the Charles River; and of Wellesley, which has a ground supply near the river:

TABLE 6. — AVERAGE DAILY WATER CONSUMPTION (GALLONS)

LOCATION	1933	1934	1935	1936	1937
Dedham	1,403,000	1,499,000	1,061,000	980,000	972,000
Newton	4,710,000	4,650,000	4,784,000	4,990,000	4,723,000
Brookline	4,609,000	4,847,000	4,792,000	4,846,000	4,730,000
Needham	730,000	803,000	824,000	661,000	672,000
Waltham	2,178,000	2,318,000	2,287,000	2,416,000	2,409,000
Cambridge	11,548,000	12,227,000	12,066,000	12,479,000	12,002,000
Wellesley	898,000	1,016,000	1,058,000	1,298,000	1,194,000
Total	26,076,000	27,360,000	26,872,000	27,670,000	26,702,000

In addition to limiting the amount of water to be taken for water-supply purposes, it also would seem advisable to reduce the amount of water which is to be diverted through Mother Brook into the Neponset River, as it is the understanding of the writer that this water is not used at the present time in the manner originally proposed.

The following diagram (Fig. 6) shows the behavior of the Charles River Basin during the period of the low upland flow of August 1 to 9, 1936:

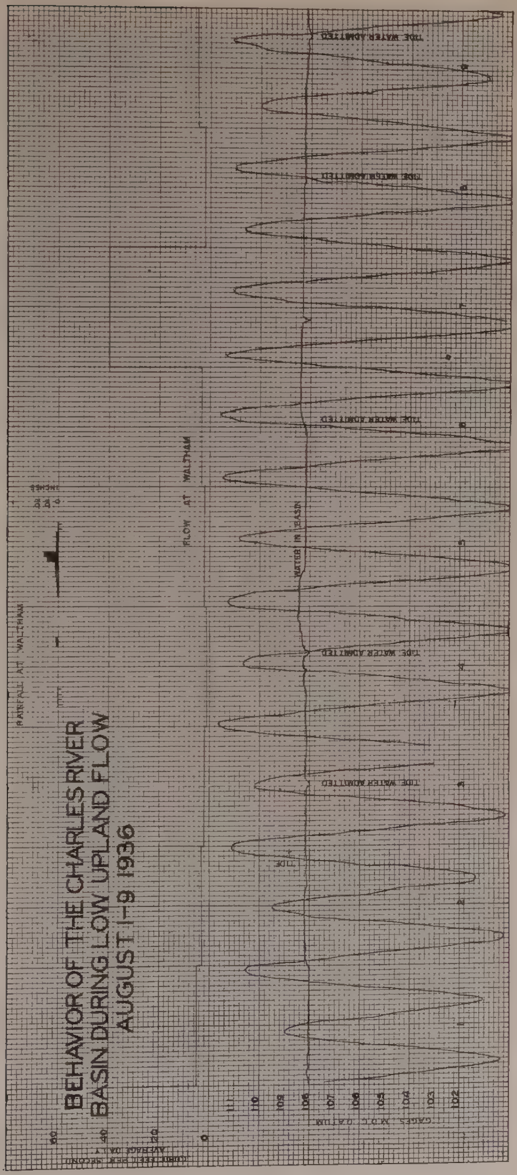

Fig. 6. — Behavior of Charles River Basin, August 1–9, 1936

Flood Flows

Stearns, in his report, stated that under average flow in the Charles River, 3,300,000,000* gallons in storage in the basin would be replaced once in every fifteen days; during the drier portions of the year, once in 82 days; while during the high flows in the spring they would be replaced as often as once a week. Under these conditions of flow he estimated that there would be a rise in the basin due to the entrance of upland waters of about one-half inch in the ordinary summer flow, 2 inches under average flow conditions, and in the wettest part of the year, about 4 inches. He assumed that a flow of 6,000 cubic feet per second would be the amount which might flow into the basin during a freshet as great as any of which there is record, and assuming that at such times successive tides considerably higher than the average occurred, water in the basin could be prevented from rising more than 2 feet above the normal. During periods of larger freshets he stated that the basin could care for such freshets, although they might cause flooding of the marshes.

On page 53 of his report of 1903 Freeman stated, in connection with the flow of the Charles River, that ". . . the Charles River is a very uncommon river, for this part of the country, in the slowness and moderation of its rise and the long duration of its run-off." He did not submit any evidence to substantiate this statement, but the hydrographs of the floods of March, 1936, and July, 1938, are sufficient evidence that Freeman was correct in his assumption. This condition is due to the immense storage available in the Dedham Meadows and the natural control of this storage by contracted sections of the river, especially in the vicinity of the silk mill dam at Newton Upper Falls. Freeman, when he wrote his report in 1903, had no measured flood discharges, but he had the estimates of Alexis French of 10,000 cubic feet per second; those of Prof. Dwight Porter and Rudolph Hering, both agreeing on 7,000 cubic feet per second; the estimate of Frederic P. Stearns of 4,900 cubic feet per second; and estimates made by Richard A. Hale that the greatest flow on record was about 3,500 cubic feet per second.

Freeman's conclusion was that —

> . . . Although the greatest flood ever known on the Charles, of which record or tradition remains, was that of February, 1886, when the flow at Waltham was prob-

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* Recent estimates show that the present capacity of the Charles River Basin below elevation 8.0 Boston city base is 3,348,750 gallons.

ably not over 4,000 cubic feet per second, and the main flood from Stony Brook and the lower tributaries had spent itself and passed before the greatest height over the Waltham dam had been attained, we will follow the prudent suggestion of the late James B. Francis, and assume a flood of much greater volume, such as might come if a rain like that of October, 1869, should fall on frozen impervious ground, and assume a flow of 7,000 cubic feet per second.

It has been interesting to make comparisons between the flows of March, 1936, and July, 1938, and the probable flow as estimated by Freeman, and especially with data relative to the estimated run-off of February, 1886. Work in this connection by George V. White, assistant engineer, Department of Public Health, would indicate that the river at the silk mill dam at Newton Upper Falls during the 1886 flood reached a height of 6 feet on the dam as compared with a measured elevation in the 1936 flood of 4.3 feet and 4.5 feet during the flood flows of July, 1938. White knows of no reason to question the reasonableness of comparing these elevations, and expresses the opinion that the run-off of the 1886 flood in the Charles River was probably greater than that of the March, 1936, or July, 1938, floods. He also is of the opinion that, although the precipitation was about the same for the 1886 and 1936 floods, there was evidence that there was a greater ground coverage of snow and ice preceding the 1886 flood in the Charles River Basin than during the March, 1936, flood. This covering of snow and ice in 1886 was said to vary from 2 to 15 inches, and had a water content equivalent to about 2 inches of water.

The following tabulation of rainfall is taken from the records of the New England Weather Bureau from February 10 to 14, 1886, of the Charles River Watershed and vicinity:

TABLE 7. — RAINFALL, FEBRUARY 10–14, 1886

	Inches		Inches
Milton	5.60	Chestnut Hill	6.09
Boston	5.62	Cambridge	5.70
Blue Hill	6.13	Framingham	4.64
Lake Cochituate	4.95	Milford	4.04
Waltham	6.08	Wellesley	5.70

Average, 5.46 inches.

On the assumption that the 2 to 15 inches of snow and ice on the ground had a water content equivalent to 2 inches, and added to the 5.46 inches of rainfall, would make about 7½ inches of rainfall. The resulting flood flow run-off as estimated by Richard A. Hale for Freeman was —

Silk mill	2,680 cubic feet per second
Boston Manufacturing Company	3,280 cubic feet per second
Through Mother Brook	900 cubic feet per second

It is stated that at the time of that run-off the flashboards were off the Boston Manufacturing Company's dam.

For comparison with the above storm the following table has been prepared, showing the rainfall on March 9 to 22, 1936:

TABLE 8. — RAINFALL, MARCH 9–22, 1936

	Inches		Inches
Chestnut Hill	4.87	Milford	4.98
Boston	4.07	Waltham	5.26
Blue Hill	4.47	Weston	4.52
Framingham	7.31	West Roxbury	4.97
Lake Cochituate	6.73	Wrentham	7.34
Newton	5.50	Millis	6.99
Franklin	6.90	Jamaica Plain	4.94

Average, 5.63 inches.

A comparison of Table 8 with Table 7, on rainfall in 1886, would indicate that the average rainfall for the storm of 1886 was 5.46 inches as compared with an average for the fourteen stations of 5.63 inches in 1936. The snow and ice cover during the March, 1936, storm was completely depleted early, and all of the precipitation was in the form of rain. Records of the United States Weather Bureau would indicate that the cover in 1936 added about 1½ inches, making a total contributing average rainfall of 7.1 inches as compared with 7.5 estimated for the 1886 storm. It is interesting to note that the estimate made of the 1886 diversion to Mother Brook was 900 cubic feet per second; the actual measured run-off in the storm of 1936 was 900 cubic feet per second; and that of July, 1938, was 910 cubic feet per second.

The great seven-day storm of July, 1938, caused the second highest gage heights in the river of which we have reliable record. Following this storm the water in the Dedham Meadows reached a height of 0.75 foot more than the March, 1936, storm, and 1.68 feet less than the storm of February, 1886. Hydrographs showing the 1936 and 1938 floods at Charles River Village and at the Dedham Meadows are presented. (Figs. 7 and 8.)

Very excessive rainfall caused the recent flood, and the increase in the peak heights may be due to back-water conditions that did not exist in March, 1936, — principally, the exuberant growth of grasses, brush, etc., in the flooded channel. The rainfall on the upland watershed, that is, above the silk mill dam, is given in the following table:

TABLE 9. — RAINFALL ON THE CHARLES RIVER WATERSHED (INCHES)

LOCATION	July 18–24, 1938	July, 1938, Total	June, 1938, Total
Newton Pumping Station	9.31	10.28	6.86
Brookline Pumping Station	8.22	9.19	7.61
Needham Pumping Station	8.80	9.61	6.75
Millis Pumping Station	9.59	11.82	7.97
Milford Pumping Station	12.29	14.52	8.78
Franklin Pumping Station	8.76	9.93	10.04
Wrentham	11.33	12.58	5.72
Average	9.76	11.13	7.68

This table shows that the great seven-day rainfall fell upon a ground well saturated. The general water table was much higher than it had been for several years at this period of the year, owing to the excessive rainfall in June and also heavy showers in July previous to the seven-day rain.

Table 10 shows a comparison of the run-off of the Charles River at certain points for the storms of 1886, 1936, and July, 1938, in cubic feet per second.

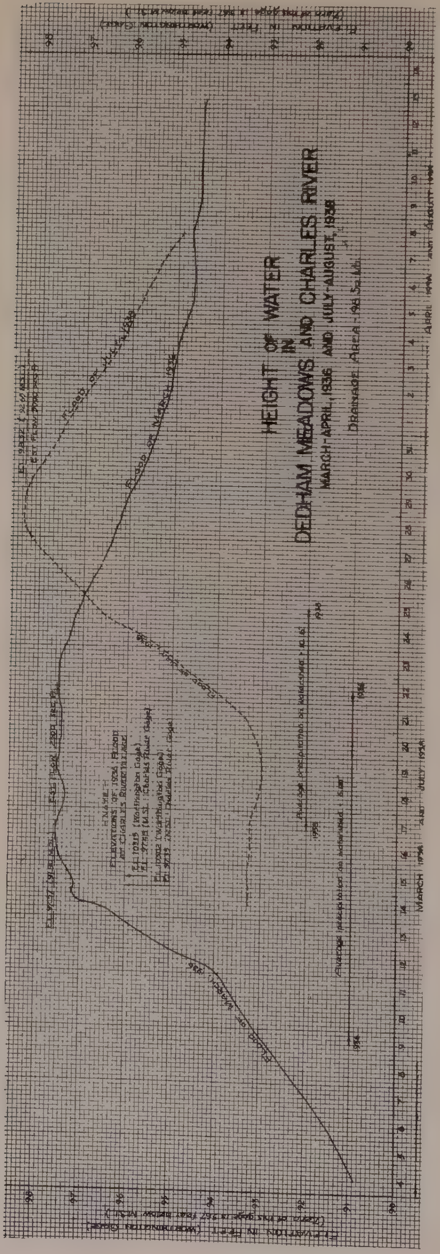

Fig. 7.—Hydrograph showing Comparison of 1936 and 1938 Floods at Dedham Meadows

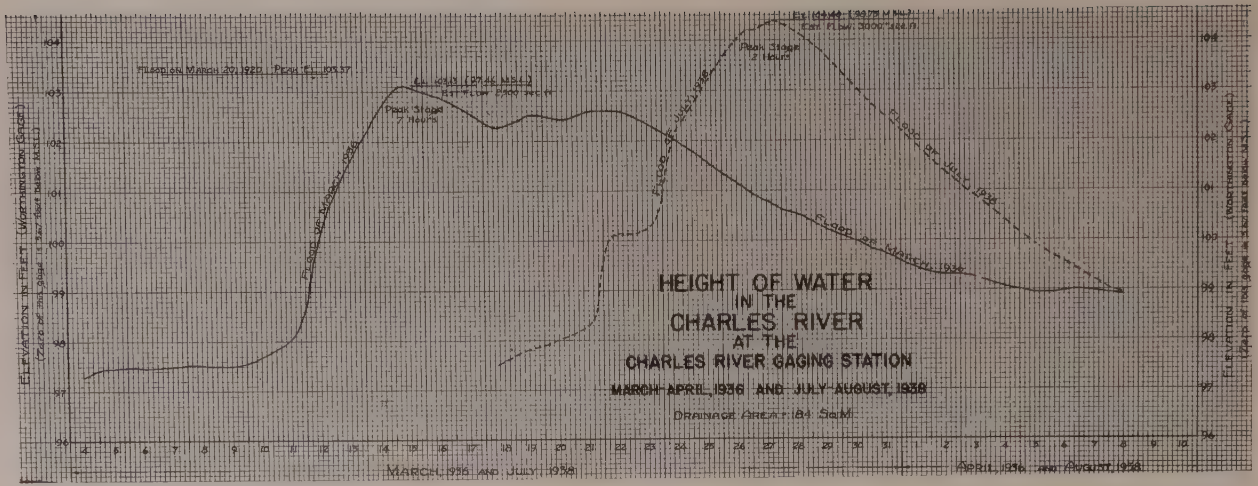

Fig. 8. — Hydrograph showing Comparison of 1936 and 1938 Floods at Charles River Village

TABLE 10. — COMPARISON OF RUN-OFF OF CHARLES RIVER AT CERTAIN POINTS FOR STORMS OF 1886, 1936, AND JULY, 1938 (CUBIC FEET PER SECOND)

LOCATION	February, 1886	March, 1936	July, 1938
Charles River at Charles River Village dam .	–	3,170*	3,070†
Mother Brook at East Street, Dedham . .	900*	900†	910†
Silk mill dam	2,680*	1,820*	–
Charles River, below Boston Manufacturing Company, Waltham	3,280*	2,540†	2,230†

* Estimates. † Measured flow.

Table 11 is presented to show the number of times that the Charles River Basin was above elevation 109 during the years from 1911 to July 31, 1938, inclusive. Freeman's report shows that the question of the behavior of the basin under excessive upland flow and adverse tidal condition was given much thought, and there were many expressions of opinion as to what might happen. The lack of flow data available aided, of course, the uncertainty of his deductions. Now we are able to show most conclusively what happens during probably two of the greatest floods on record in the Charles River Valley, although it appears that the flood of 1886, on the Charles River Watershed, may have been greater. A following chart (Fig. 9) shows the behavior of the basin during the flood periods, March 15 to 24, 1936, and from July 19 to August 1, 1938. This latter chart also shows the flow at Waltham in cubic feet per second, the rainfall at Boston, and the hourly elevation of both the basin and the tide. It will be noted that the basin reached only grade 109.20,* and that the tide went to 112.50 during the 1936 flood and to 109.77 and 112.77, respectively, during the 1938 flood. On the ebb tide of the 1936 flood the basin was drawn down to elevation as low as 107.30, but immediately filled, and in 1938 to elevation 107.40. Fig. 6 shows the behavior of the basin during a period of very little upland flow, averaging only about 8.0 cubic feet per second for a week. This low flow occurred in August, 1936. It will be noted that by borrowing sea water on the flood tide the basin is maintained at the prescribed elevation of 108.0.* It will be noted from Table 11 that in spite of the extreme run-off in any month the elevation of the water in the basin did not exceed 109.88.*

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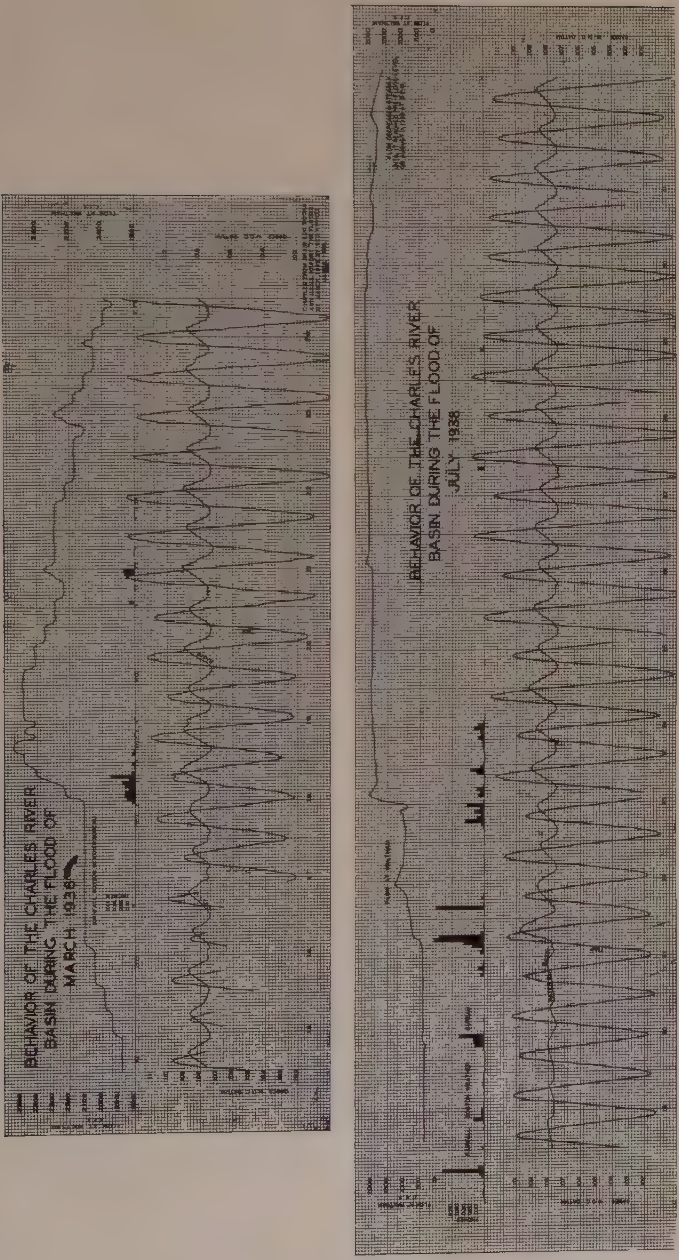
* Metropolitan District Commission Sewer Division base.



BEHAVIOR OF THE CHARLES RIVER BASIN DURING THE FLOOD OF MARCH 1936

BEHAVIOR OF THE CHARLES RIVER BASIN DURING THE FLOOD OF JULY 1938

FIG. 9. — BEHAVIOR OF CHARLES RIVER BASIN DURING FLOODS OF MARCH, 1936, AND JULY, 1938

TABLE 11. — SHOWING THE NUMBER OF TIMES THAT THE CHARLES RIVER BASIN WAS ABOVE ELEVATION 109.00 FROM JANUARY 1, 1911, TO AUGUST 1, 1938

YEAR	Date	Time	Gage	Rainfall (Inches)
1911	July 28	3.00 P.M.	109.05	3.78
		3.30 P.M.	109.10	
		4.00 P.M.	109.05	
1915	July 1	7.01 A.M.	109.06	5.00
		7.30 A.M.	109.17	
		8.00 A.M.	109.22	
		8.30 A.M.	109.01	
	Aug. 4	6.00 P.M.	109.00	1.95
		6.30 P.M.	109.05	
		7.00 P.M.	109.11	
		7.30 P.M.	109.16	
		8.00 P.M.	109.19	
		8.30 P.M.	109.20	
		9.00 P.M.	109.15	
1917	Aug. 10	7.00 A.M.	109.09	3.17
		7.30 A.M.	109.21	
		8.00 A.M.	109.24	
		8.30 A.M.	109.25	
		9.00 A.M.	109.27	
		9.30 A.M.	109.18	
		10.00 A.M.	109.01	
	Oct. 24	8.00 A.M.	109.05	1.70
		8.30 A.M.	109.16	
		9.00 A.M.	109.22	
		9.30 A.M.	109.21	
		10.00 A.M.	109.03	
1918	Jan. 12	12.36 P.M.	109.01	0.79
		12.57 P.M.	109.05	
		1.30 P.M.	109.07	
		2.00 P.M.	109.02	
	Jan. 15	3.39 P.M.	109.03	0.61
		3.59 P.M.	109.05	
		5.03 P.M.	109.10	
		5.31 P.M.	109.05	
1920	Mar. 24	4.00 P.M.	109.07	0.73
1921	May 1	8.30 A.M.	109.03	1.90
		9.00 A.M.	109.11	
		9.30 A.M.	109.20	
		10.00 A.M.	109.03	
	July 9	5.00 A.M.	109.14	1.86
		5.30 A.M.	109.22	
		6.00 A.M.	109.07	

TABLE 11. — SHOWING THE NUMBER OF TIMES THAT THE CHARLES RIVER BASIN WAS ABOVE ELEVATION 109.00 FROM JANUARY 1, 1911, TO AUGUST 1, 1938 — *Continued*

YEAR	Date	Time	Gage	Rainfall (Inches)
1922	June 27	6.03 A.M.	109.03	–
		6.34 A.M.	109.05	
1924	Aug. 26	12.31 P.M.	109.01	4.15
	Sept. 10	8.57 A.M.	109.02	4.57
		9.30 A.M.	109.15	
		10.00 A.M.	109.28	
		10.30 A.M.	109.42	
		11.30 A.M.	109.54	
		12.00 M.	109.57	
		12.30 P.M.	109.45	
		1.00 P.M.	109.30	
		1.30 P.M.	109.09	
1927	Oct. 13	12.07 P.M.	109.03	1.51
		12.29 P.M.	109.13	
		12.57 P.M.	109.22	
		1.32 P.M.	109.31	
		2.04 P.M.	109.36	
		2.30 P.M.	109.40	
		2.59 P.M.	109.46	
		3.27 P.M.	109.45	
		4.26 P.M.	109.03	
1928	Oct. 20	4.57 A.M.	109.00	1.49
		5.30 A.M.	109.09	
		6.00 A.M.	109.10	
	Oct. 23	10.30 P.M.	109.00	1.07
1929	Feb. 7	10.26 A.M.	109.00	1.24
		10.55 A.M.	109.19	
		11.27 A.M.	109.31	
		11.55 A.M.	109.38	
		12.26 P.M.	109.45	
		12.56 P.M.	109.40	
		1.28 P.M.	109.15	
	Apr. 16	6.01 P.M.	109.00	1.95
		6.30 P.M.	109.13	
		7.05 P.M.	109.30	
		7.35 P.M.	109.40	
		8.02 P.M.	109.47	
		8.30 P.M.	109.53	
		9.00 P.M.	109.47	
		9.35 P.M.	109.27	
		10.05 P.M.	109.03	

TABLE 11.— SHOWING THE NUMBER OF TIMES THAT THE CHARLES RIVER BASIN WAS ABOVE ELEVATION 109.00 FROM JANUARY 1, 1911, TO AUGUST 1, 1938 — *Continued.*

YEAR	Date	Time	Gage	Rainfall (Inches)
1929	Apr. 29	6.35 A.M.	109.00	–
		7.03 A.M.	109.00	
		7.28 A.M.	109.00	
1931	Feb. 18	1.32 P.M.	109.05	–
		1.57 P.M.	109.12	
	Mar. 9	6.00 P.M.	109.05	–
		6.35 P.M.	109.05	
	June 9	7.05 P.M.	109.09	5.64
		8.32 P.M.	109.23	
		8.58 P.M.	109.30	
		9.28 P.M.	109.39	
		10.02 P.M.	109.55	
		10.30 P.M.	109.62	
		11.00 P.M.	109.82	
		11.30 P.M.	109.77	
	June 10	12.00 M.	109.61	–
		12.28 A.M.	109.47	
		1.00 A.M.	109.29	
		1.30 P.M.	109.07	
		10.28 P.M.	109.05	
	June 16	2.00 P.M.	109.02	2.77
		2.25 P.M.	109.01	
	June 17	2.58 A.M.	109.08	–
		3.33 A.M.	109.19	
		4.00 A.M.	109.24	
		4.28 A.M.	109.24	
	June 18	4.36 A.M.	109.03	–
		5.02 A.M.	109.04	
		5.30 A.M.	109.05	
		6.04 A.M.	109.04	
		6.31 A.M.	109.03	
	Aug. 12	4.32 P.M.	109.00	1.88
1932	Sept. 16	2.05 P.M.	109.20	–
		2.38 P.M.	109.32	
		3.03 P.M.	109.41	
		3.32 P.M.	109.52	
		4.05 P.M.	109.42	
		4.35 P.M.	109.30	
		5.02 P.M.	109.02	
	Nov. 10	10.02 A.M.	109.05	–
		10.31 A.M.	109.27	

TABLE 11. — SHOWING THE NUMBER OF TIMES THAT THE CHARLES RIVER BASIN WAS ABOVE ELEVATION 109.00 FROM JANUARY 1, 1911, TO AUGUST 1, 1938 — *Continued*

YEAR	Date	Time	Gage	Rainfall (Inches)
1932	Nov. 10	10.59 A.M.	109.50	
		11.28 A.M.	109.63	
		11.58 A.M.	109.87	
		12.30 P.M.	109.88	
		1.01 P.M.	109.69	
		1.33 P.M.	109.48	
		2.03 P.M.	109.16	
		2.31 P.M.	108.95	
1933	Mar. 8	11.29 A.M.	108.93	–
		12.00 M.	109.01	
		12.31 P.M.	108.85	
	Sept. 16	9.32 A.M.	109.01	–
		10.03 A.M.	109.24	
		10.29 A.M.	109.50	
		11.05 A.M.	109.59	
		11.33 A.M.	109.59	
		12.04 P.M.	109.54	
		12.31 P.M.	109.36	
		1.01 P.M.	109.12	
	Sept. 17	1.35 P.M.	109.06	–
		2.03 P.M.	109.03	
1934	Apr. 1	1.32 A.M.	108.91	–
		2.05 A.M.	109.02	
		2.33 A.M.	109.06	
1935	June 18	12.29 A.M.	109.10	–
		1.01 A.M.	109.15	
		1.32 A.M.	109.21	
		2.01 A.M.	109.26	
		2.31 A.M.	109.32	
		3.00 A.M.	109.33	
		3.27 A.M.	109.37	
		4.00 A.M.	109.41	
		4.33 A.M.	109.43	
		5.04 A.M.	109.44	
		5.31 A.M.	109.32	
		6.02 A.M.	109.15	
	Aug. 22	7.00 P.M.	109.14	–
		7.35 P.M.	109.20	
		7.58 P.M.	109.22	
		8.30 P.M.	109.26	
		9.00 P.M.	109.34	

TABLE 11. — SHOWING THE NUMBER OF TIMES THAT THE CHARLES RIVER BASIN WAS ABOVE ELEVATION 109.00 FROM JANUARY 1, 1911, TO AUGUST 1, 1938 — *Concluded*

YEAR	Date	Time	Gage	Rainfall (Inches)
1935	Aug. 22	9.32 P.M.	109.27	
		10.00 P.M.	109.09	
1936	Mar. 12	3.28 P.M.	109.04	–
		3.55 P.M.	109.14	
		4.20 P.M.	109.12	
		4.49 P.M.	109.03	
	Mar. 13	3.28 A.M.	109.01	–
		3.57 A.M.	109.15	
		4.32 A.M.	109.24	
		4.59 A.M.	109.35	
		5.31 A.M.	109.26	
		6.03 A.M.	109.15	
		6.29 A.M.	109.05	
	Mar. 19	9.57 A.M.	109.06	–
		10.30 A.M.	109.02	
	Mar. 21	11.57 A.M.	109.07	–
		12.28 P.M.	109.12	
1937	Dec. 7	3.30 A.M.	109.07	–
		4.00 A.M.	109.12	
		4.31 A.M.	109.14	
		5.00 A.M.	109.05	
1938	July 21	7.07 P.M.	109.27	–
		7.28 P.M.	109.46	
		7.58 P.M.	109.76	
		8.32 P.M.	109.77	
		8.55 P.M.	109.69	
		9.25 P.M.	109.61	
		9.52 P.M.	109.47	
		10.30 P.M.	109.30	
		11.00 P.M.	109.00	

The drawdown of the water on the Dedham Meadows can be somewhat accelerated through the co-operation of the silk mill owners by discharging water through their wheeels twenty-four hours a day for several days.

Additional discharge area is necessary in the vicinity of the silk mill, and can be reasonably obtained by the removal of obstructions in the river channel above the dam, and by the construction of an additional spillway under the mill of possibly 25 feet in length, which would increase the spillway area some 60 per cent.

Possible Nuisance or Menace to the Public Health from the Accumulations of Organic Matter in Basin

The joint board in their report (House Document No. 775 of 1894) expressed the opinion that there would be no nuisance or menace to the public health from the accumulations of organic matter by reason of the construction of the dam, and Stearns in his report expressed the opinion that, if sewage would not enter the river except in small amounts which might overflow during heavy rainfall, conditions would be entirely changed from those of sewage being discharged into the tidal estuary of the Charles before the dam was built. Freeman expressed a similar opinion in his report. These opinions appear to have been borne out by actual experience in so far as there have been no nuisances from the depletion of oxygen, but conditions have arisen resulting from the overflow of sewage which are not satisfactory.

The special committee, in their report under chapter 105 of the Resolves of 1901, stated, in connection with the use of the basin for recreation —

> . . . under reasonable conditions, it ought to become the scene, for at least four or five months of the year, of a great popular play ground. . . .
>
> . . . As this basin is to be used for park purposes, it is essential that the condition of the water should not only be harmless to health, but also that there should be no suggestion of sewage; that the wastes be as pure as reasonably possible and thus both the factor of sanitary safety and the enjoyment of the water park be increased. . . .
>
> . . . It is important to preserve the greatest possible water area. . . . the surface of the river should not be encroached upon more than is necessary. . . .

It is obvious that those who designed the basin did not contemplate its use to such an extent for bathing as has been the case, and those responsible for its construction undoubtedly believed that, as Stearns stated, only limited amounts of dilute sewage would overflow during heavy rains. An investigation made jointly by the Department of Public Health and the Metropolitan District Commission, a report on which has been published as House Bill No. 159 of 1932, showed that the Charles River Basin was polluted to a considerable extent by the overflow of sewage, especially from the Charles River Valley sewer of the South Metropolitan Sewerage District, and two plans were suggested for the relief of this condition: (1) to provide for the extension of the high level sewer in Brighton to Newton and thence across the city of Newton to intercept a portion of the sewage of that city; and (2) to provide a pumping station for pumping sewage from the Charles River Valley sewer in the vicinity of Faneuil into the high level sewer by an independent line. The first of these plans has in part been carried out, but the latter has not, and large quantities of sewage continue to be discharged into the basin at times of storm, resulting in a large number of bacteria in the water. In 1935 and 1936 the matter of the pollution of this basin was further investigated, this time by a special commission consisting of the Commissioner of the State Department of Public Works, the State Commissioner of Public Health, the Commissioner of the Metropolitan District Commission, the Health Commissioner of the city of Boston, and the Commissioner of Public Works of Boston. The sewer-overflows described in Table 12 and shown on the following map (Fig. 10), are described in the special commission's report published as House Document No. 1600 of 1937.

TABLE 12. — OVERFLOW OF SEWAGE INTO CHARLES RIVER BASIN

Cambridge Branch Sewer

REFERENCE NUMBERS		LOCATION OF OUTLET	SIZE	TYPE
House, No. 1600	Metropolitan Connection Number			
		Cambridge		
4	4	Mount Auburn and Lowell streets	24″	Regulator
5	5	Mount Auburn at Sparks Street	15″	Regulator
6	6	Mount Auburn at Willard Street	12″	Regulator
7	7	Mount Auburn at Hawthorne Street	18″	Regulator
8	8	Charles River at Binney Street	48″	Tide gates
9	9	Charles River at Granite Street and Brookline Street	10″	Regulator
10	10	Charles River at Dunster Street	24″ x 24″	Regulator
11	12	Charles River at Eliot Square	15″	Regulator
12	13	Pearl Street at Granite Street	30″ x 36″	Regulator
13	14	Charles River at Pleasant Street	20″	Regulator
14	15	Charles River at Waverly Street	20″	Regulator
15	16	Charles River at Western Avenue	22″	Regulator
17	19	Charles River at Albany and Pacific streets	18″	
19	39	Charles River at Hingham Street	8″	Regulator
23	11	Dyke and Plympton streets	30″	Regulator
24	18	Albany Street at Massachusetts Avenue	18″	Regulator
25	21	Albany and Erie streets	18″	Regulator

TABLE 12. — OVERFLOW OF SEWAGE INTO CHARLES RIVER BASIN — *Continued*

Charles River Valley Sewer

Reference Numbers		Location of Outlet	Size	Type
House, No. 1600	Metropolitan Connection Number			
		Brighton		
36	7	Charles River at Faneuil Station . . .	9″ x 20″ wood	–
37	9	Charles River at Parsons Street	5′ x 5′ wood	Regulator
39	3	Charles River at Western Avenue . . .	30″ x 39″ brick	Regulator
40	1	Charles River at Cambridge Street	30″ x 36″ brick	Regulator
41	5	Charles River at Babcock Street	7′ 6″ x 7′ 0″ concrete	–
XI	Trunk	Charles River at St. Mary's Street	84″ x 89″	Regulator
XII	Trunk	Parson's Brook at Electric Avenue . . .	12′ 8″ x 11′ 0″ brick	–
		Roxbury		
	Local	Charles River at Deerfield Street	9′ x 11′	Muddy River conduit
		Brookline		
1	Local	Muddy River at playground	48″ x 66″	High level sewers
		Newton		
1	1	Hyde Brook at Maple Street	24″	Regulator
2	2	Charles River at Crescent Street and California Street	24″ x 36″	Regulator
3	3	Charles River at Charlesbank Road . . .	10″	Regulator
		Waltham		
1	1	Charles River at Farwell Street and Calvary Street	34″ x 51″	–
2	Local	Charles River at Beaver Brook	–	–
3	Local	Charles River at Mica Lane	–	–

TABLE 12. — OVERFLOW OF SEWAGE INTO CHARLES RIVER BASIN — *Continued*

Charles River Valley Sewer — Concluded.

REFERENCE NUMBERS		LOCATION OF OUTLET	Size	Type
House, No. 1600	Metropolitan Connection Number			
		Watertown		
	Local	Charles River at Galen Street	–	Regulator
	5	Charles River at United States Arsenal . .	18″	Tide gates

TABLE 12. — OVERFLOW OF SEWAGE INTO CHARLES RIVER BASIN — *Concluded*

Boston Main Drainage System

Reference Number, House, No. 1600	LOCATION OF OUTLET	Size	Type
	Boston		
44	Back Bay, Charlesgate West .	–	–
45	Back Bay, Charlesgate East, gate chamber . . .	–	–
46	Back Bay, Gloucester Street marginal conduit . .	6′ x 6′ concrete	Elev. 8.5
47	Back Bay, Exeter Street from marginal conduit . .	6′ x 6′	Elev. 8.5
48	Back Bay, Berkeley Street from marginal conduit .	10′ x 7′ approximate	Elev. 8.5
49	Boston, northwest, south of Pinckney Street from marginal conduit . . .	6′ x 6′ wood	–
50	Boston, northwest, between Fruit and Cambridge streets	5′ 3″ x 6′ 5″	–
52	Boston, northwest, west of Charles Street between Poplar and Chambers streets from marginal conduits .	2–7′ 8″ x 6′ 4″ concrete	Upper lock gate house

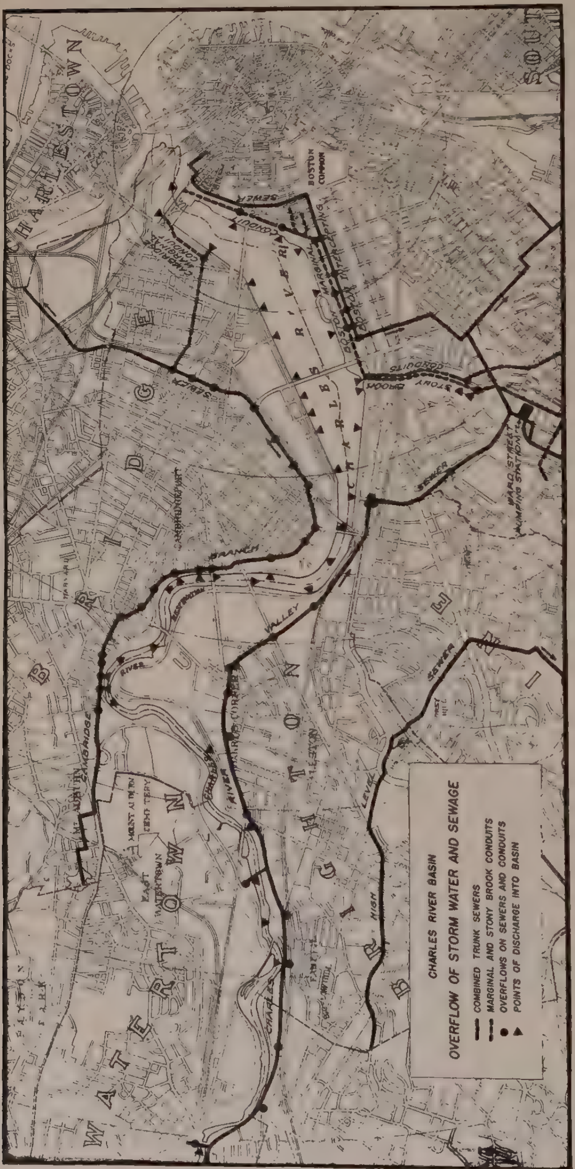


FIG. 10. — OVERFLOW OF STORM WATER AND SEWAGE INTO CHARLES RIVER BASIN

Because of the possible effect of the pollution of this basin on bathers it was necessary for the Massachusetts Department of Public Health to make a rather extended study in 1933, and the results of this study showed that at Magazine Beach on the Charles River, where at times several thousand children bathe, the density of coliform organisms varied from 100 to 55,000 per 100 c.c., and that the bacteriophages B. dysenteriae Sonne, B. paratyphosus B., B. dysenteriae Shiga, B. dysenteriae Hiss-Y, B. coli communis and B. typhosus were present. The bacterial load at this beach was the greatest of any beaches examined by the Department that summer. A remedy for these conditions has been proposed by the Department of Public Health with the Metropolitan District Commission, in House Bill No. 187 of 1938, which would provide for additional sewage facilities in the Charles River Valley. In addition to the construction of a new trunk sewer from the vicinity of the Newton–Waltham line to a pumping station to be located in the Faneuil section of Brighton, and the facilities for pumping the sewage reaching this pumping station out of the valley of the Charles River into the high level sewer of the South Metropolitan Sewerage System, the old Charles River Valley sewer would have to be used as a relief sewer, and the present marginal conduit probably would have to be extended to the vicinity of Faneuil to intercept the overflow of mingled storm water and sewage from the Charles River Valley sewer between Faneuil and the Ward Street Pumping Station. To prevent the overflow of sewage from the present marginal conduit may necessitate pumping facilities near the Charles River Dam and additional marginal conduit capacity. In addition it would be necessary to extend the marginal sewer on the Cambridge side of the basin.

Pollution of the Charles River Basin has never reached the point whereby the oxygen content has been depleted to such an extent as to result in a nuisance, although the oxygen content of this body of water has been found by tests of the Department of Public Health to be as low as 25 per cent saturation. In general, the oxygen content has been in excess of 50 per cent saturation.

The following table shows the bacterial condition of the water of Magazine Beach on the Charles River Basin and other beaches during recent years:

TABLE 13. — SHOWING AVERAGE RESULTS OF BACTERIAL EXAMINATIONS OF WATER AT MAGAZINE BEACH ON THE CHARLES RIVER BASIN AND VARIOUS OTHER BATHING BEACHES OUTSIDE THIS BASIN

Date of Collection	Number of Samples	Location	COLI-AEROGENES GROUP PER CENT POSITIVE IN PORTIONS EXAMINED					
			.001 c.c.	.01 c.c.	.1 c.c.	1 c.c.	10 c.c.	
							Positive	Negative
1916	4	Magazine Beach, Cambridge	0	50	100	100	100	0
1928	19	Magazine Beach, Cambridge	5*	21	57	89	100	0
1929	5	Magazine Beach, Cambridge	0	0	60	80	100	0
1930	7	Magazine Beach, Cambridge	0	57	86	100	100	0
1931	17	Magazine Beach, Cambridge	12	59	94	100	100	0
1932	2	Magazine Beach, Cambridge	0	0	100	100	100	0
1933	51	Magazine Beach, Cambridge	4	25	75	100	100	0
1935	14	Magazine Beach, Cambridge	7	50	71	100	100	0
1937	13	Magazine Beach, Cambridge	0	31	69	100	100	0
1924	5	Crystal Lake, Newton	0	0	0	80	100	0
1926	17	Crystal Lake, Newton	0	0	0	35	71	29
1927	7	Crystal Lake, Newton	0	0	0	14	71	29
1928	13	Crystal Lake, Newton	0	0	0	15	46	54
1931	2	Crystal Lake, Newton	0	0	0	0	0	100
1933	27	Crystal Lake, Newton	0	0	0	33	78	22
1934	3	Crystal Lake, Newton	0	0	0	33	33	67
1924	2	Frog Pond, Boston Common	0	0	0	100	100	0
1926	3	Frog Pond, Boston Common	0	0	0	100	100	0
1928	13	Frog Pond, Boston Common	0	0	0	54	100	0
1931	6	Frog Pond, Boston Common	0	33	100	100	100	0
1933	10	Frog Pond, Boston Common	0	0	40	90	100	0
1924	6	Nantasket Beach†	0	0	0	17	50	50
1926	11	Nantasket Beach	0	0	0	36	100	0
1928	3	Nantasket Beach	0	0	0	33	100	0
1924	5	Revere Beach†	0	0	0	0	80	20
1926	7	Revere Beach	0	0	14	57	100	0
1927	45	Revere Beach	0	0	2	49	100	0
1928	17	Revere Beach	0	0	0	55	100	0
1933	14	Revere Beach, south	0	0	14	29	79	21
1933	13	Revere Beach, north	0	0	8	23	85	15
1933	14	Revere Beach, center	0	0	7	29	79	21
1937	4	Revere Beach	0	0	0	25	100	0

* Also 5 per cent of .0001 c.c. portions.

† Salt water.

The following diagrams and table (Figs. 11, 12, 13, 14 and Table 14) show the amount of dissolved oxygen and biochemical oxygen demand in the water of the basin, the chloride content of the water, and the bacterial condition, and fluctuations in the amount of organic matter as represented by the albuminoid ammonia and free ammonia determinations.

The monthly variations are shown for the year 1937 rather than for 1938, as conditions during 1938 were not normal because of excessive rainfall and because it would be impracticable at the time of the printing of this report to supply data for the full year of 1938.

Monthly variations for 1914 and 1915 are shown as those years are the only reasonably dry years that analyses are available for the full twelve months.

TABLE 14. — CONDITION OF WATER IN THE CHARLES RIVER BASIN — AVERAGE ANALYSIS, JUNE TO NOVEMBER, 1937

	Coli-Aerogenes Index (per 100 c.c.)	Chlorides (p.p.m.)	AMMONIA		Bio-chemical Oxygen Demand (p.p.m.)	Oxygen (Per Cent) Saturation
			Free	Albuminoid (p.p.m.)		
Watertown Dam	398	11	.097	.307	1.7	80.6
North Beacon Street	1,000	54	.142	.315	2.8	81.5
Cottage Farm bridge	372	294	.190	.365	2.2	79.3
Harvard bridge	725	558	.236	.399	3.3	85.8
West Boston bridge	1,380	680	.271	.400	2.9	89.8
Charles River Dam	1,000	–	–	–	–	–

It is interesting to compare the preceding tables and diagrams with the following statements from the report of the Committee on the Charles River Dam.

Quoting from the report of the biologist working under his direction Freeman states:

> Just as by experiment in a balanced aquarium the amount of vegetation necessary to balance an excess of plant food could be added, so in the proposed Charles River basin a growth of algæ would soon become established sufficient to care for such polluting organic material as now comes over the Watertown dam or is likely to enter with the street wash.
>
> . . . And, as to danger from excessive growths of algæ, which by their decay would produce malodorous or unsightly conditions, such as have happened not infre-

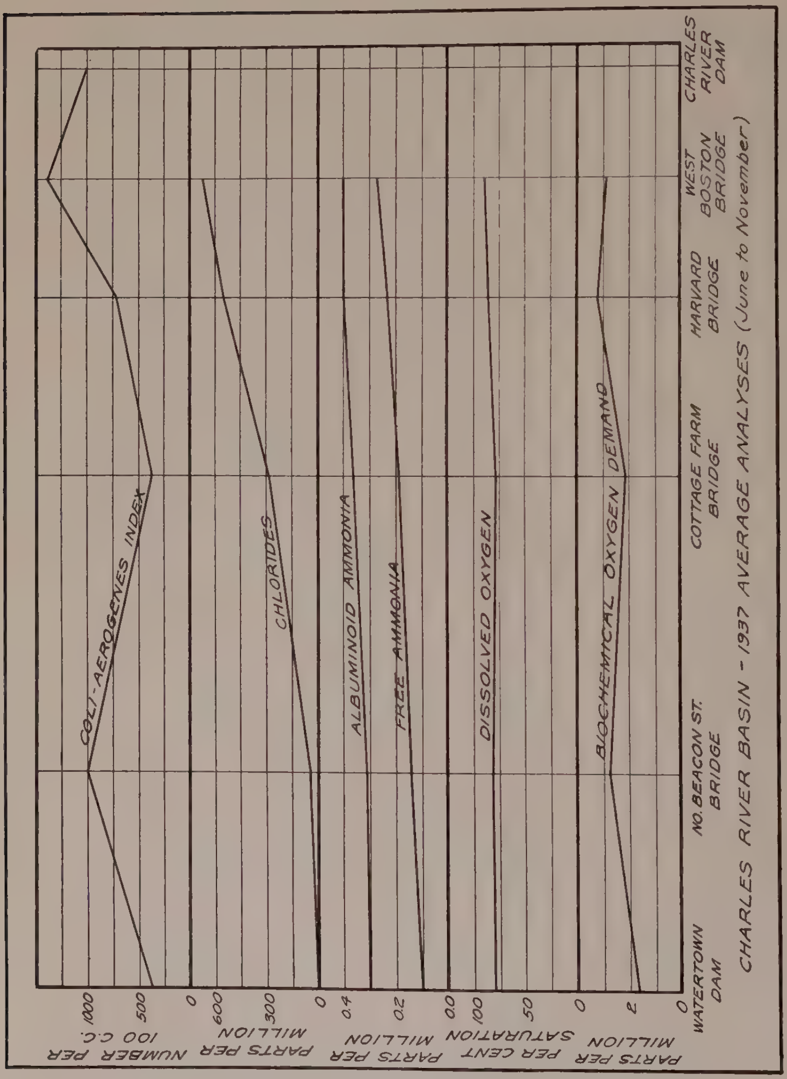


FIG. 11.—AVERAGE ANALYSES OF WATER FROM CHARLES RIVER BASIN JUNE–NOVEMBER, 1937

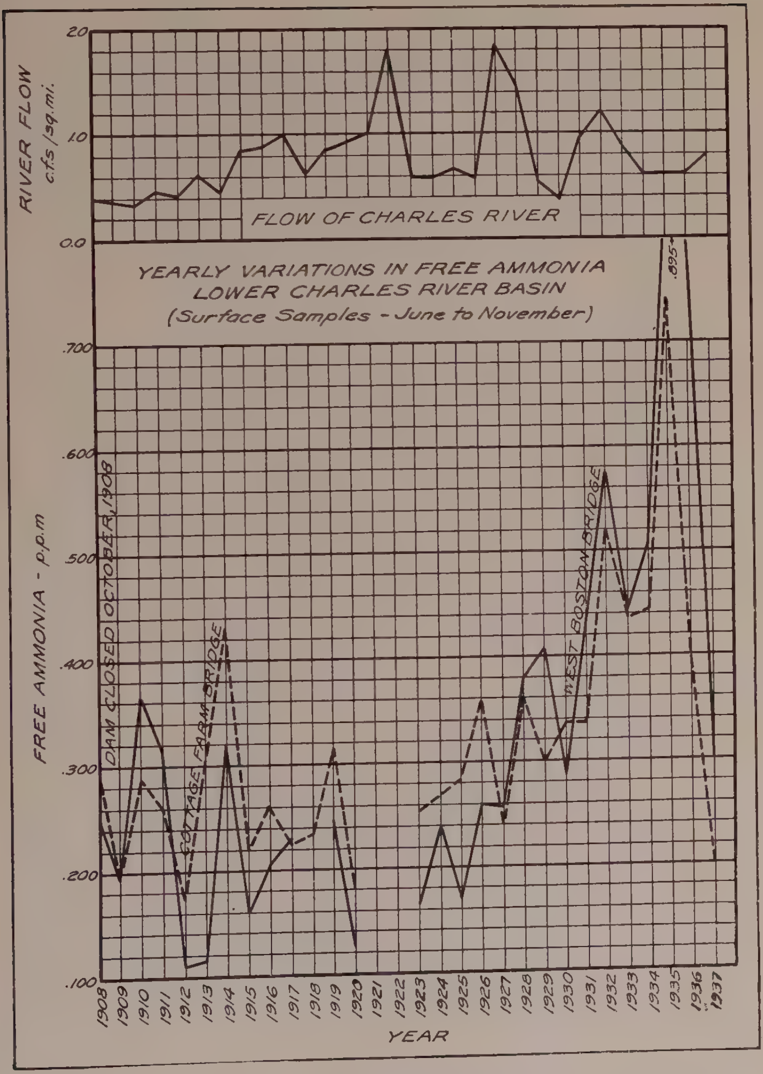


FIG. 12. — YEARLY VARIATIONS IN FREE AMMONIA, LOWER CHARLES RIVER BASIN

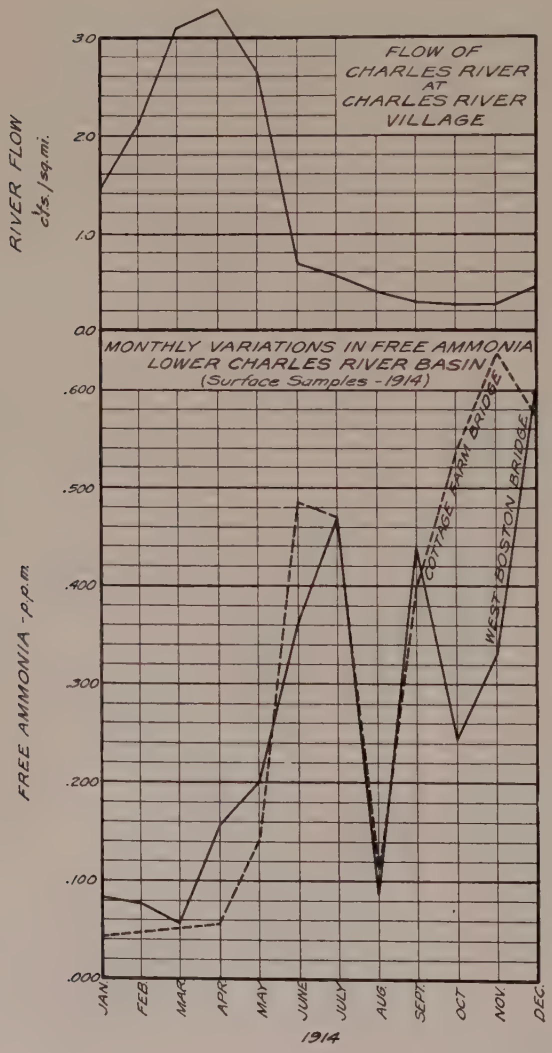


FIG. 13. — MONTHLY VARIATIONS IN FREE AMMONIA, LOWER CHARLES RIVER BASIN

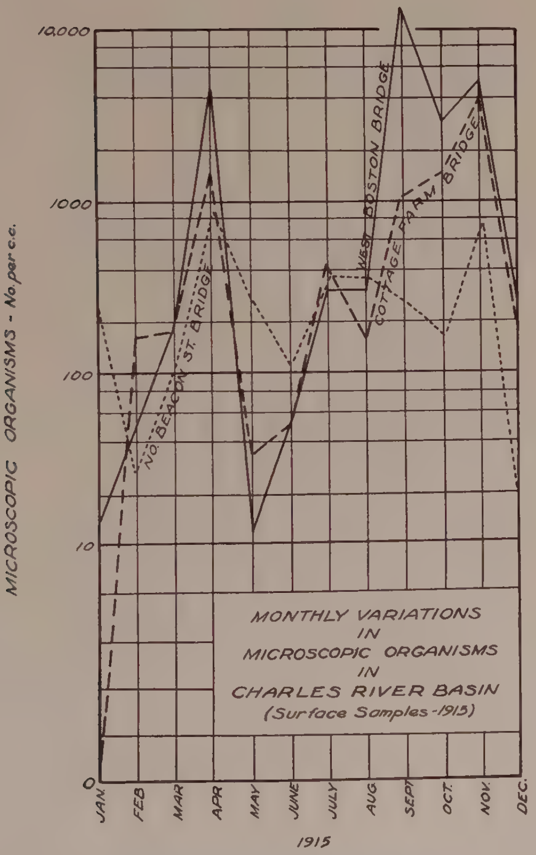


FIG. 14. — MONTHLY VARIATIONS IN MICROSCOPIC ORGANISMS IN CHARLES RIVER BASIN, 1915

quently in certain storage reservoirs for water supply, he states that, with care given to lessening the pollution and with conditions favorable to the life of organisms that browse on the algæ, trouble from this source appears extremely improbable, although remotely possible. While it is true that pollution of water by nitrogenous substances directly promotes the growth of aquatic plants, these same plants do much to justify their existence by producing oxygen (and thus tending to check putrefaction) and by assimilating the nitrified polluting material.

. . . It is probable that proper precautions may avoid the likelihood of an excessive growth of algæ, which might, in dying, become offensive.

Relative to the growth of algæ in the basin:

The biologist (Appendix No. 6, p. 316) says: "It appears to me highly probable that it" [the proposed Charles basin, containing 458,000,000 cubic feet of fresh water, of the quality now found above Watertown dam, refilled in hot weather at least once each one hundred days, and having a surface of 1.27 square miles favorably exposed to sun and wind] "can assimilate the assumed amount of sewage" [equivalent to the continuous ordinary flow from 10,000 persons], "together with the present, and probably the future, amount of street wash, without causing offence."

Clark in his studies in 1902 found that the water as it entered the upper end of the basin at the Watertown dam was —

. . . fairly clear, low in color, practically odorless, only the odor of vegetable matter being noted; containing a comparatively small amount of organic matter, . . . and containing from 60 to 74 per cent of the volume of dissolved oxygen necessary for saturation.

In summarizing his studies Clark stated —

It is exceedingly improbable, in view of the results of the experiments given, that all the wastes now entering the basin would under any circumstances rob the still fresh water in the proposed basin of its dissolved oxygen. . . . If . . . the sewage of more than 13,000 people, amounting to 1,000,000 gallons per day, should enter the basin daily, it would require more than a month's flow to cause the volume of entering sewage to reach 1 per cent of the capacity of the basin. . . . the volume of sewage entering each day could . . . for a considerable period, without causing offence, amount to . . . 1 per cent of the capacity of the basin *if this sewage was well distributed throughout the waters of the basin*. . . . with such drainage removed as has been indicated in this report, the water of the basin would always contain a plentiful supply of free oxygen, even though at times of storm a large volume of sewage should enter from the overflows.

It is hardly possible and certainly not probable, that any of the mud banks, with two or three exceptions, contain enough organic matter to decay rapidly enough, even in a still basin, to rob the water of its oxygen and over-saturate it with the gaseous products of decay. Moreover, even with the dam built, it could not possibly be a basin of still water, as there will always, even in the dryest seasons, be a slight current, and such movements of the water as are caused by wind and changes in temperature.

> . . . Growths of organisms are likely to occur in almost any pond. Large growths of algæ sometimes occur, which, by becoming stranded on the shores, owing to a lowering of the water level, produce odors when decaying.

An examination of Table 13, relative to bacterial examination of samples of water from Magazine Beach on the Charles River Basin, shows that the number of bacteria of the Coli-Aerogenes group is greatly in excess of that generally found in waters considered safe for bathing. In this connection it might be stated that neither Freeman nor Clark probably considered that the basin would be used as extensively for bathing as has been the case.

Chloride Content of Water in Basin

John R. Freeman, in his report for the special committee published in 1903, stated —

> The occasional introduction of salt water into the basin should be avoided.
>
> . . . I had some predisposition to favor a clean salt-water basin on anything like equal terms, particularly after having observed the pleasure of the children bathing and learning to swim at the Captain's Island playground. But a preliminary study soon led me to conclusions so different from the popular view, as expressed above, that I requested the pathologist, the biologist and the chemist each to take up this question from his own field of view, and to make his investigations independently of his associates. *Each of these experts independently reported that, in his opinion, the fresh-water basin would prove the better.*
>
> If absolutely pure ocean water could be had in the Charles and kept free of pollution, a different conclusion might have been reached; but this is plainly impossible, and the varying quantity of upland water precludes a brackish basin of the constant salinity requisite for the best development of marine life. . . .

In both the special report of the State Board of Health and the Metropolitan District Commission herein referred to, and the report of the Committee on the Charles River Dam, mention is made of the probable salinity of the water of the basin.

In Appendix IV of the committee's report, H. W. Clark, consulting chemist for the committee, discussed the probable salinity of the basin prior to the construction of the dam, as follows:

> . . . I find that the larger portion of the lower part of the estuary . . . contains at high tide a body of salt water with a slight but fairly even admixture of fresh water, the proportion of fresh water increasing towards the upper portion of the basin. . . . The salt water coming into the basin from the harbor is found by chemical analysis to be fairly low in organic matter, contains a comparatively small amount of free ammonia — although much greater than the amount present in pure sea water — and

> free oxygen is present at all depths. The main portion of this water contains at the present time from two to three times as much organic matter as pure sea water, as shown by the analysis of a sample of water collected off the Boston Lightship, six miles from Boston Light.
>
> The waters of practically the entire estuary at the present time are, under ordinary conditions and at high tide of a fairly attractive appearance. Local pollutions occur, but these are not noticeable over any considerable area except at times of storm, when large areas are often discolored and of an offensive appearance because of these pollutions, especially at low tide.

The tables of analyses submitted by Clark show that the chloride content of the basin from the early ebb to the mid ebb tide on September 4, 1902, before the dam was built, varied from 16,200 parts per million at Harvard bridge to about 12,500 parts per million at Upper Western Avenue bridge. The chloride content of the fresh water entering the basin at the Watertown dam near high tide on October 6, 1902, he found to be 9 parts per million. He also showed by comparison that, while the chloride content of the water at Harvard bridge at about high tide was about 16,000 parts per million, at low tide it varied from about 13,700 to 15,500 parts per million, and at lower Western Avenue bridge, from 7,650 parts per million at low tide to about 15,100 parts per million at high tide. He found little difference in the chloride content of the water at the surface and at depths in the lower part of the basin, although there was quite a considerable difference in the salt content between the surface and bottom waters at a station about one mile above the Harvard bridge according to the direction of the tide. For example, about two hours after low tide the water at the surface at this site had a chloride content of 13,980 parts per million, and at a depth of 3 feet it was 15,450 parts per million.

Clark found that salt water held less oxygen in solution than fresh water, and that its capacity for oxygen decreased when it was concentrated by evaporation. He expressed the opinion that, "volume for volume, fresh water can receive the greater amount of pollution without the exhaustion of the oxygen if bacterial life is of equal vigor in each case." *

Clark further expressed the opinion that —

> Better conditions would prevail with the basin filled with still fresh water than if filled with still salt water or brackish water; that is, certain experiments and observations already given seem to show that in a basin with a bottom of Charles River mud, and with certain drainage entering, better conditions prevail if the water is all fresh,

---

* More recent studies by the Department of Public Health show that bacterial life is not of equal vigor in salt and fresh water, and that salt water has a certain germicidal action.

> than when salt, or when the bottom layer of water is salt with fresh water above. There is the constant tendency for precipitation to occur in salt water, and hence concentration of the organic matter of entering sewage in the form of putrefying sludge banks; while in fresh water more even mixing and distribution of this matter throughout the oxygen-bearing water occurs. The examinations of water from different depths in the Fens, where the bottom layer is salt, also go to prove this statement. The fresh surface water entering the Fens is badly polluted, and constant deposition of organic matter is taking place, causing putrefaction and the exhaustion of oxygen from the salt water. . . .
>
> Under present conditions at times of storm, the turbid water flowing into the Charles River basin is carried over large areas by the movement of the tides, especially as, being fresh water, it flows over the surface of the salt water. It is doubtful if in a still basin the turbid water would be carried over these large areas as it would mingle with the entire depth of water, especially if this water were fresh.

Speaking of the relative merits of a fresh-water basin *versus* a salt-water basin, the Special Committee on the Charles River Dam stated in the conclusions of their report:

> Fresh water, gallon for gallon, disposes in a normal manner of more sewage than salt water; the tendency of salt water is rapidly to precipitate sewage in sludge at the bottom. . . .
>
> Letting in salt water under the fresh interferes with the vertical circulation necessary for oxygenation, and the salt water under the fresh soon loses its oxygen if any waste material is admitted into it.
>
> Changing a fresh water basin into a salt from time to time interferes with the bacterial animal and vegetable growths, which effectively aid in taking care of and digesting sewage.
>
> A comparatively still body of fresh water with animal and plant growths will dispose of a considerable amount of sewage admitted from time to time, and will tend to purify itself, even if no more fresh water is added.
>
> Such a body of fresh water will dispose of more sewage if comparatively still than if in motion.

Morton F. Sanborn in his paper published on March 10, 1910, Vol. 63, No. 10, of the "Engineering News," estimated that the large boat or ship lock in the Charles River Dam contains between grade −13 and half tide, 283,500 cubic feet, and that this average amount of salt water flows into the basin at every lockage. In this same paper Mr. Sanborn gives some very interesting results of tests made by him to show the diminution of salt water in the basin after the gates were closed on October 20, 1908, also the stratification of salt and fresh water. Unfortunately, Sanborn's tests did not take place over a long enough period of time at all the sampling points to obtain a clear picture of the change of salinity in the basin.

More recent observations made by the writer show that the salinity of water in the present basin is influenced to a considerable extent by the amount of sea water admitted intentionally to maintain the level of water in the basin sufficiently high during periods of drought.

The following diagrams (Figs. 15, 16 and 17) show a comparison between the present chloride content of the basin and that found prior to the construction of the dam, average yearly variations of chlorides from 1908 to date, and monthly variations in chlorides during a period of drought.

Drainage of Low Lands, and Malaria

The special committee under chapter 105 of 1901 reported that —

> Considered merely as an engineering project, there can be no question as to the feasibility of constructing a dam and of maintaining a basin above it at constant grade, even in times of freshet flow of the river, and this without flooding the Back Bay districts and without obstructing the existing storm sewage overflows.
>
> . . . It will make the following report more clear if it is at once stated that the committee, early in its investigations, was led to believe that, whether such basin were fresh or salt, a dam, if built at all, must be high enough to keep out high tides, and that it must be supplied with a lock for the accommodation of river navigation.

It was the prediction of Stearns and other investigators that, as expressed by Freeman in the chief engineer's report —

> The holding of the basin at a constant level between grade 8 and 9 instead of the present frequent rise to grade 11, and *restricting the highest necessary storm level to grade 11 at high tide, in the greatest storm of half a century*, instead of the occasional tides of 14 feet, and with an extreme record of 15.67 feet above Boston base, *would give improved sanitary conditions* throughout portions of the Back Bay district of Boston and throughout portions of Cambridge by lowering the extreme flood level in the present sewer and storm-water drains, and thereby give almost *absolute relief from liability to such overflows of sewage into cellars and over certain low territory as are reported to now not infrequently occur* during extremely heavy rainfalls at high tide.

Under present conditions of drainage the lands in the vicinity of the river formerly flooded at times of extreme high tide, especially in the Brighton and Cambridge sections, are now well drained and not subject to such flooding. Improvements in such lands are to be seen in the park lands and playgrounds in Brighton, Newton, Boston and Cambridge, the further development of Soldiers Field and the construction of dormitories and other buildings by Harvard University.

Whether or not improved drainage conditions in the Charles River Basin have been responsible for a reduction in the cases of malaria in

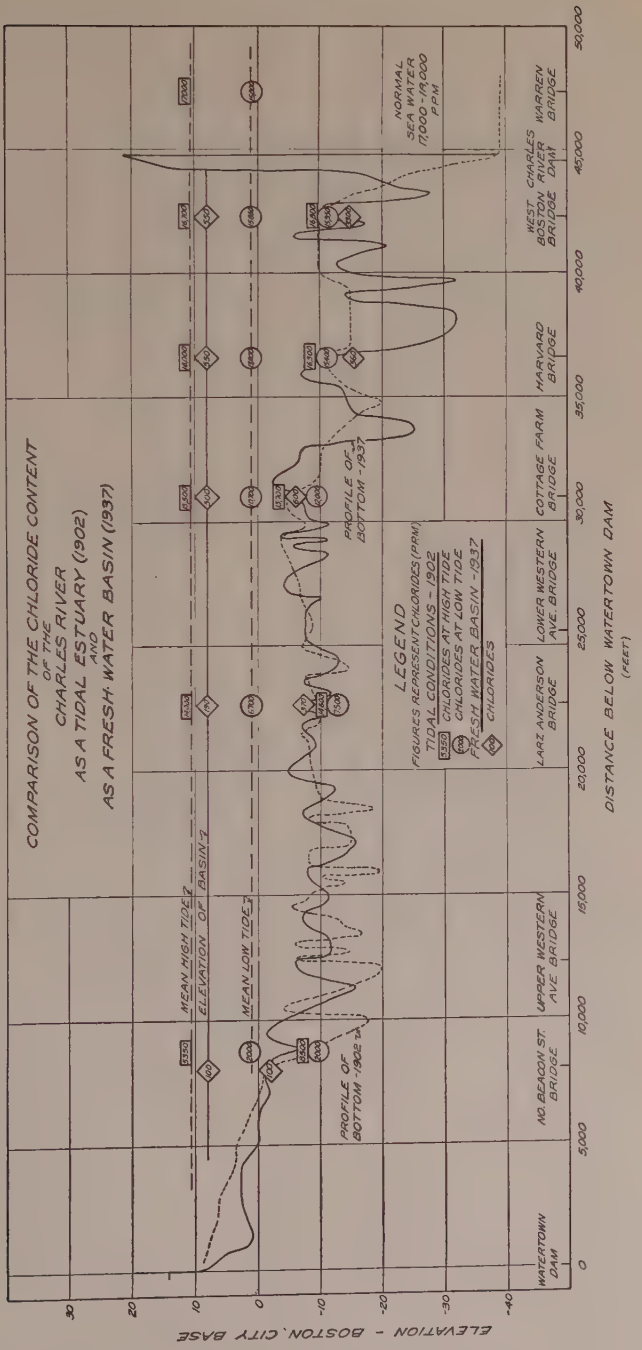


FIG. 15. — COMPARISON OF CHLORIDE CONTENT OF BASIN

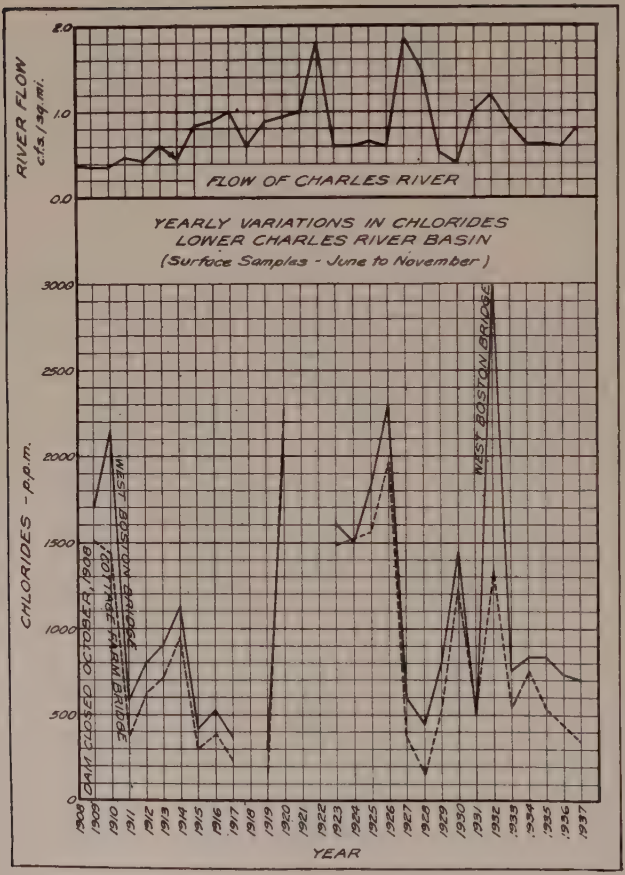


FIG. 16.—YEARLY VARIATIONS IN CHLORIDES, LOWER CHARLES RIVER BASIN

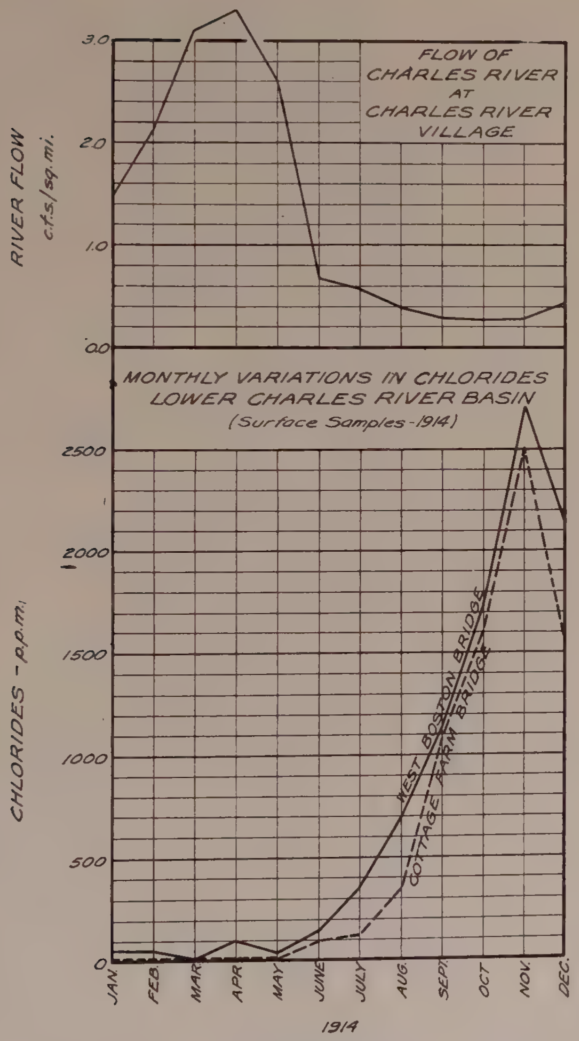


Fig. 17. — Monthly Variations in Chlorides, Lower Charles River Basin

the vicinity of the basin would be difficult to prove, but the fact that the construction of the basin has improved drainage conditions in the vicinity and has reduced the prevalence of pestiferous mosquitoes is readily seen by an examination of those areas now well drained and which prior to the construction of the basin were flooded by various high tides. The following map (Fig. 18) shows the areas found by Theobald Smith to be breeding places for mosquitoes.

According to Dr. C. E. Waller, assistant surgeon general, United States Public Health Service, malaria has never been a serious problem of this State, but it did prevail with some transmission of the disease during the period of immigration from south European countries.

According to Dr. Roy L. Feemster, Director of the Division of Communicable Diseases of the Department of Public Health, it would be difficult to prove that any reduction in malaria in Cambridge and Boston was due to the improved drainage conditions resulting from the construction of the Charles River Basin, for two reasons: (1) that it is doubtful in his opinion that malaria mosquitoes will breed in brackish water, and (2) because of the difference in the diagnosis of malaria at the present time as compared with the period in the vicinity of 1908. Many cases may have been reported as malaria in earlier years which were not malaria. Feemster stated:

> . . . The diagnosis of malaria in recent years has been made upon entirely different grounds from what it was made in earlier days. Now a physician is usually not willing to make such a diagnosis without actually seeing the malaria parasite in blood smears taken from the patient. Twenty-five years ago the diagnosis was very likely to be made when a patient had an irregular temperature which cleared up after the administration of quinine. Consequently the more recent the figures the more confidently we can depend upon the diagnosis which was made. . . . no Anopheles mosquitoes that breed in brackish water in this country have been found to be important carriers of malaria. The principal mosquito which breeds in brackish water is Anopheles crucians. This mosquito has played only a very minor rôle in spreading the disease. On the other hand, the Anopheles quadrimaculatus is the important carrier of malaria in the United States. It is never found breeding in brackish water. Any Anopheles mosquitoes found in the marshes flooded by the tides in the Charles River Basin in the lower portions of the Valley would therefore probably be Anopheles crucians, whereas those that were found breeding in bodies of water left by tides higher up, where no salt water was found, might possibly have been Anopheles quadrimaculatus and may have played a part in the spread of malaria some years ago.

Table 15 shows the number of reported cases of malaria in Boston and Cambridge from 1915 to 1937, inclusive.

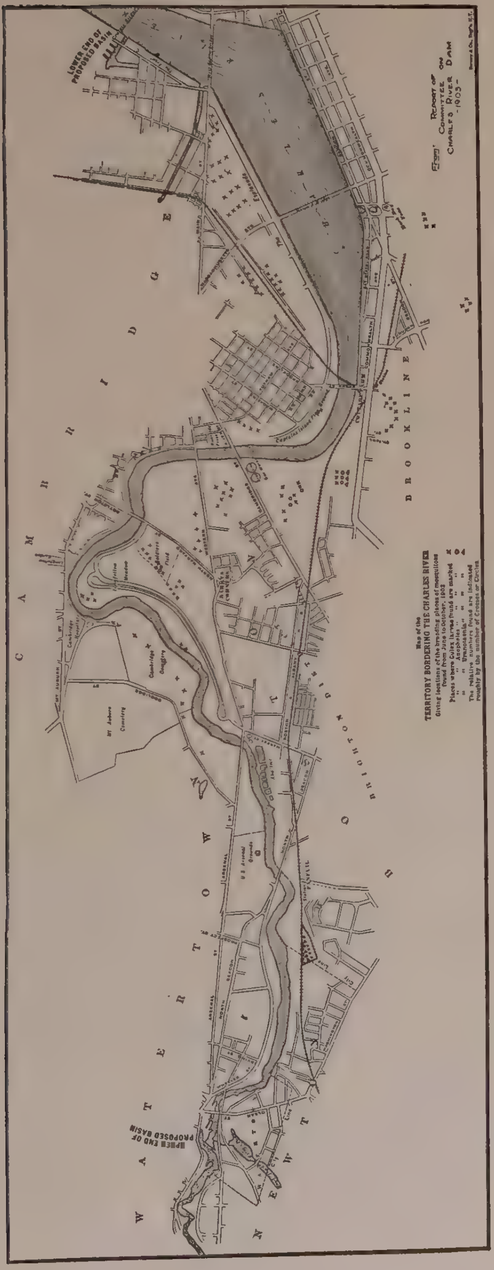

LOWER END OF PROPOSED BASIN
UPPER END OF PROPOSED BASIN
CAMBRIDGE
BROOKLINE
BRIGHTON
WATERTOWN
NEWTON
Esplanade
Mt Auburn Cemetery
Cambridge Cemetery
U S Arsenal Grounds
Soldiers Field
Longfellow Meadow
From Report of Committee on Charles River Dam 1903
Map of the
TERRITORY BORDERING THE CHARLES RIVER
Giving locations of the breeding places of mosquitoes found from June to October, 1902
Places where Culex larvae found are marked ✕
" " Anopheles " " " " ●
" " Uranotaenia " " " " ▲
The relative numbers found are indicated roughly by the number of Crosses or Circles

FIG. 18. — MOSQUITO BREEDING PLACES ALONG LOWER CHARLES RIVER, 1902

TABLE 15. — CASES OF MALARIA, BOSTON AND CAMBRIDGE

	Boston		Cambridge		Case Rates for Five-year Periods	
	Cases	Case Rate	Cases	Case Rate	Boston	Cambridge
1915	28	3.8	1	.9	2.5	1.1
1916	17	2.3	2	1.8		
1917	24	3.2	2	1.8		
1918	13	1.7	1	.9		
1919	11	1.5	–	–		
1920	15	2.0	2	1.8	1.9	1.2
1921	18	2.4	–	–		
1922	21	2.8	1	.9		
1923	9	1.2	2	1.7		
1924	10	1.3	2	1.7		
1925	4	.5	1	.8	.6	.3
1926	8	1.0	–	–		
1927	4	.5	–	–		
1928	6	.8	1	.9		
1929	1	.1	–	–		
1930	6	.8	–	–	.4	.5
1931	2	.3	–	–		
1932	–	–	2	1.7		
1933	1	.1	–	–		
1934	7	.9	1	.8		
1935	5	.6	1	.8	.3	.5
1936	2	.2	–	–		
1937	2	.2	1	.8		

It should be stated in connection with the preceding table that malaria was not a reportable disease until 1915, and that in earlier years no differentiation was made in reporting cases between those originating in the State and those coming into the State from the outside. Accordingly, the source of infection in some cases may not have been in Boston or Cambridge.

The following table, prepared under the direction of the Division of Communicable Diseases of the Department of Public Health, shows the deaths from malaria in Boston and Cambridge from 1894 to 1937, inclusive:

TABLE 16. — DEATHS FROM MALARIA, BOSTON AND CAMBRIDGE

[Malaria deaths by cities not available before 1894]

YEAR	Boston	Cambridge	YEAR	Boston	Cambridge
1894	5	1	1916	–	–
1895	6	2	1917	–	–
1896	6	–	1918	–	–
1897	1	1	1919	–	–
1898	5	1	1920	–	–
1899	1	–	1921	–	–
1900	6	–	1922	–	–
1901	1	1	1923	–	–
1902	8	–	1924	1	–
1903	–	–	1925	1	–
1904	2	–	1926	–	–
1905	2	–	1927	–	–
1906	1	–	1928	–	–
1907	2	–	1929	–	–
1908	4	–	1930	2	–
1909	–*	–*	1931	1	–
1910	1	–	1932	–	–
1911	4	1	1933	1	–
1912	1	1	1934	–	–
1913	–	–	1935	1	–
1914	–	–	1936	–	–
1915	–	–	1937	2	–

* 1909 deaths not available by cities.

EFFECT ON BOSTON HARBOR

While it was rather definitely proven by the special committee appointed under the Resolves of 1901 that the construction of the dam and the operation of the basin would not have an unfavorable effect on Boston Harbor by shoaling, studies in 1926 by the United States Coast and Geodetic Survey show that, in spite of the changes in the vicinity of Boston Harbor, including the filling of a large area of land near East Boston in the construction of the East Boston Airport, the closing of Shirley Gut, the dredging of the harbor and filling of sections in the vicinity of Castle Island, the direction and velocity of the tidal flow in Boston Harbor off the mouth of the Charles River has not changed greatly. A comparison of the tidal conditions in 1902 and in 1926 is shown in the following table and diagram (Table 17 and Fig. 19):

TABLE 17. — MAXIMUM TIDAL CURRENTS — FLOOD AND EBB TIDES — AT CERTAIN SECTIONS IN BOSTON HARBOR IN 1902 AND 1926

[Velocities in feet per second]

Depth	Boston and East Boston			
	Charles River Investigation, 1902		Coast and Geodetic Survey, 1926	
	Flood	Ebb	Flood	Ebb
Surface	1.52	1.52	.73	.84
3	1.48	1.33	–	–
6	–	–	.74	.91
7	–	–	.70	.86
8	–	–	.68	1.08
12	1.65	1.62	.74	.91
17	–	–	.63	.79
18	1.49	1.69	.74	.91
19	–	–	.83	.84
24	1.65	1.33	–	–
28	–	–	.64	.73
30	–	–	.90	.73
35	1.10	1.05	–	–

TABLE 17. — MAXIMUM TIDAL CURRENTS — FLOOD AND EBB TIDES — AT CERTAIN SECTIONS IN BOSTON HARBOR IN 1902 AND 1926 — *Continued*

[Velocities in feet per second]

Depth	Governors Island and Castle Island			
	Charles River Investigation, 1902		Coast and Geodetic Survey, 1926	
	Flood	Ebb	Flood	Ebb
Surface	1.69	2.54	1.46	1.69
2	1.62	2.40	–	–
3	–	–	1.23	1.57
1	–	–	1.48	1.69
8	1.79	2.64	1.50	1.59
13	–	–	1.69	1.60
16	1.79	2.37	1.64	1.84
17	–	–	1.35	1.62
22	1.79	1.45	–	–
26	–	–	1.62	1.64
28	–	–	1.27	1.38
32	1.01	1.10	–	–

TABLE 17. — MAXIMUM TIDAL CURRENTS — FLOOD AND EBB TIDES — AT CERTAIN SECTIONS IN BOSTON HARBOR IN 1902 AND 1926 — *Continued*

[Velocities in feet per second]

DEPTH	DEER ISLAND AND LONG ISLAND			
	CHARLES RIVER INVESTIGATION, 1902		COAST AND GEODETIC SURVEY, 1926	
	Flood	Ebb	Flood	Ebb
Surface	2.54	2.86	2.82	2.65
3	2.54	2.86	–	–
7	–	–	2.79	2.55
11	–	–	2.50	3.01
13	–	–	2.98	2.47
16	–	–	2.77	2.33
21	2.86	3.01	–	–
26	–	–	2.57	2.23
28	–	–	2.40	2.91
32	2.46	3.08	2.70	2.42
42	2.54	2.47	–	–
45	–	–	2.40	2.91
51	–	–	2.37	2.26
63	2.23	1.62	–	–

TABLE 17. — MAXIMUM TIDAL CURRENTS — FLOOD AND EBB TIDES — AT CERTAIN SECTIONS IN BOSTON HARBOR IN 1902 AND 1926 — *Concluded*

[Velocities in feet per second]

DEPTH	MOON ISLAND AND LONG ISLAND			
	CHARLES RIVER INVESTIGATION, 1902		COAST AND GEODETIC SURVEY, 1926	
	Flood	Ebb	Flood	Ebb
Surface	.51	.68	.68	.68
2	–	–	.61	.85
3	.54	.78	–	–
6	.46	1.00	–	–
7	–	–	.61	.68
12	.46	.42	.59	.61
17	.54	.51	–	–

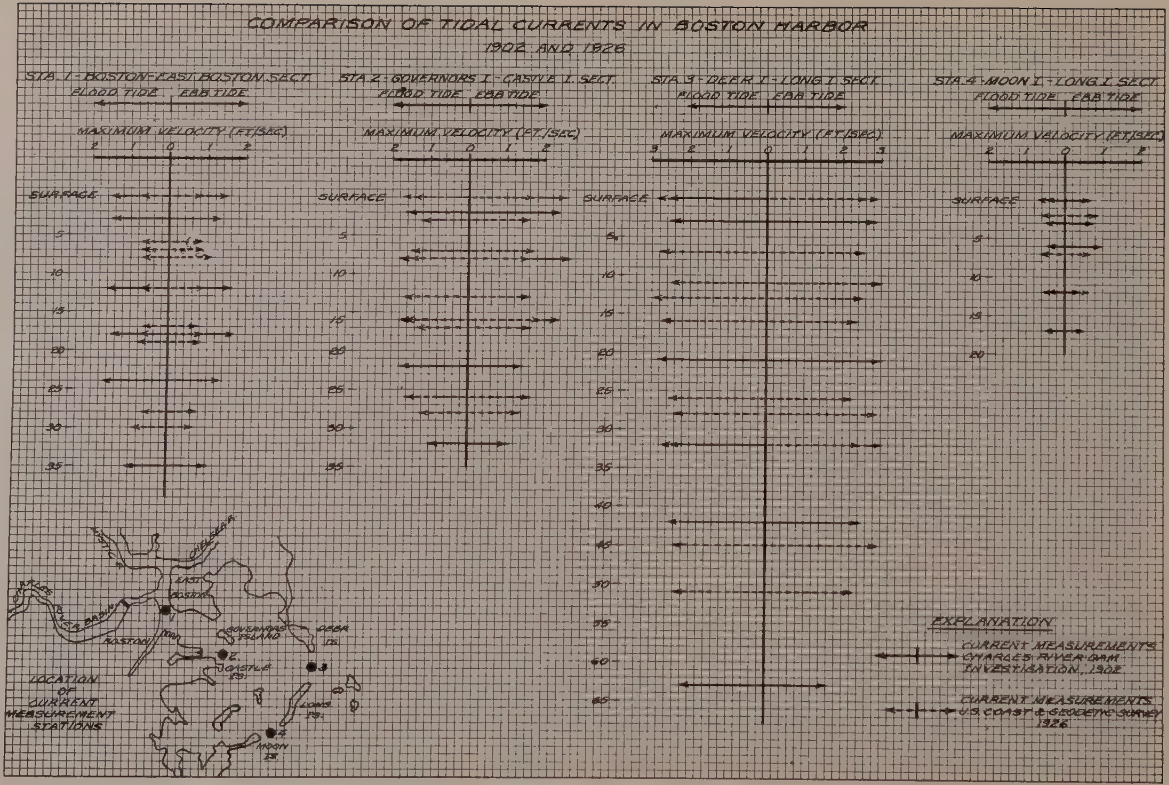


FIG. 19. — COMPARISON OF TIDAL CONDITIONS, 1902 AND 1926

FORMATION OF ICE ON THE BASIN

It was the conclusion of the joint board (chapter 475, Acts of 1893) that the formation of ice on the basin in the absence of any considerable amount of commerce would have no unfavorable effect and would afford the use of the river for skating. The river has been well adapted for skating, and during the past winter, especially, large numbers of persons have used the upper part of its area for this purpose. It was estimated in 1903 that the cost of keeping the basin open for traffic by ice-breaking would be about $4,000 per year. The actual annual costs for this work are shown in the following table:

TABLE 18. — COST OF ICE-BREAKING IN CHARLES RIVER BASIN AND BROAD AND LECHMERE CANALS

YEAR	Cost	Work done by —
1910–11	$3,674 21	Chartered tugboat
1911–12	3,955 41	Chartered tugboat
1912–13	689 05	Chartered tugboat
1913–14	4,630 47	Chartered tugboat
1914–15	1,988 31	Chartered tugboat
1915–16	3,899 02	Chartered tugboat
1916–17	6,510 90	Chartered tugboat
1917–18	11,293 41	Chartered tugboat
1918–19	16,677 36*	Metropolitan District Commission boat
1919–20	20,670 64†	Metropolitan District Commission boat
1920–21	6,149 23	Metropolitan District Commission boat
1921–22	4,612 38	Metropolitan District Commission boat
1922–23	9,000 00	Contract
1923–24	13,855 88	Department of Public Safety with hired boat
1924–25	13,449 60	Department of Public Safety police boat
1925–26	10,463 69	Department of Public Safety police boat
1926–27	8,899 75	Department of Public Safety police boat

* Included cost of boat ($10,500) which was purchased for this purpose.

† Exceptionally severe winter. Some outside assistance obtained from towboat companies.

TABLE 18. — COST OF ICE-BREAKING IN CHARLES RIVER BASIN AND BROAD AND LECHMERE CANALS — *Concluded.*

YEAR	Cost	Work done by —
1927–28	$6,600 00	Contract
1928–29	6,200 00	Contract
1929–30	5,000 00	Contract
1930–31	4,500 00	Contract
1931–32	4,475 00	Contract
1932–33	4,200 00	Contract
1933–34	4,000 00	Contract
1934–35	4,000 00	Contract
1935–36	4,000 00	Contract
1936–37	6,000 00	Contract
1937–38	4,500 00	Contract

TRAFFIC THROUGH CHARLES RIVER BASIN

The special committee appointed under chapter 105 of the Acts of 1901 expressed the opinion that —

> The construction of a dam with a proper system of locks and with such dredging as is indicated below will, in the judgment of the committee, rather facilitate than hinder this traffic. The formation of ice in the winter will be a possible objection, and an estimate of the probable expenditure necessary to protect the annual traffic has been prepared.

An examination of the records of the Metropolitan District Commission shows that the number of vessels entering the Charles River Basin after the basin was completed in 1908 increased from about 3,546 in 1911 to 7,505 in 1926, and since that time there has been a decrease in the number of vessels entering the basin, in 1937 there being 2,029. There has been a constant increase in the number of small boats entering and leaving the basin. This number increased from 2,225 in 1911 to 7,128 in 1937. The dropping off in traffic in 1926 to date probably can be explained, in part, at least, to the industrial depression, but a further study may show that a decrease in the cost of transportation by trucks plays an important part.

Statistics relative to traffic through the Charles River Basin obtained from the Metropolitan District Commission are shown in the following table:

TABLE 19. — TRAFFIC THROUGH CHARLES RIVER DAM

	Lock Openings	Number of Vessels	Number of Small Boats	Coal (1,000 Tons)	Sand (1,000 Tons)	Gravel (1,000 Tons)	Lumber (Feet B. M.)	Oil (Thousand Barrels)*
1937	4,353	2,029	7,128	15	176	74	14,557,500	601
1936	4,043	2,543	6,162	82	136	56	2,467,900	612
1935	3,933	2,325	5,256	125	133	39	103,000	847
1934	3,655	2,042	4,965	126	117	39	–	831
1933	3,264	2,056	3,951	128	88	33	98,000	737
1932	3,730	2,950	3,660	167	223	52	100,000	607
1931	3,702	4,187	2,585	229	273	107	542,600	599
1930	3,517	4,156	2,310	530	245	119	1,907,100	530
1929	3,394	4,286	1,922	295	288	109	1,712,000	580
1928	3,859	6,216	1,537	269	392	174	3,695,000	631
1927	2,763	6,864	2,517	273	407	181	2,034,000	623
1926	4,767	7,505	2,131	269	427	200	1,663,500	651
1925	5,098	7,363	2,649	183	415	170	1,874,000	709
1924	4,531	5,855	2,926	279	255	166	2,610,000	1,508
1923	4,024	4,743	2,774	290	188	92	4,556,700	–
1922	3,678	3,855	2,510	226	171	103	3,590,800	471
1921	3,531	2,912	3,257	260	102	43	2,361,300	299
1920	3,716	3,291	2,712	217	141	62	1,388,000	384
1919	2,455	2,313	1,415	193	109	62	1,379,000	238
1918	2,497	2,771	1,456	286	70	64	1,965,000	203
1917	3,133	3,609	1,377	328	136	67	6,300,000	180
1916	3,626	4,163	1,604	390	128	72	10,662,000	146
1915	3,338	3,315	2,215	348	163	23	8,543,000	150
1914	3,485	3,727	2,233	381	56	9	19,056,000	144
1913	4,115	4,343	3,002	394	72	10	22,630,000	156
1912	3,333	4,013	1,888	340	39	2	31,796,000	165
1911	3,209	3,546	2,225	335	29	3	23,487,000	145
1910†	1,920	1,727	1,906	135	2	11	11,562,000	63

* Does not include bulk oil.

† Figures given cover only the half year that the dam was under the control of the Metropolitan District Commission.

EFFECT OF CHARLES RIVER BASIN ON DRAINAGE CONDITIONS IN BACK BAY SECTION OF THE CITY OF BOSTON

Maintenance of the basin at grade 8, Boston city base, has been responsible for improved sanitary conditions in the South End of Boston by the carrying out of the South End Sewerage System of the city of Boston, which has an outlet at Union Park Street and improved drainage conditions in the Back Bay section of the city of Boston, especially in the vicinity of the Fens and Stony Brook, where certain channels were previously obstructed, and where large areas were overflowed at times of high tide and large quantities of sewage were discharged on the low stages of the tide. There has been some discussion as to whether or not the maintenance of the basin at this elevation has resulted in damage to the foundations of the Boston Public Library, Trinity Church and other places in the Back Bay by lowering the ground water table, thus permitting the piles to deteriorate. The data published by Bayard F. Snow, of X. Henry Goodnough, Inc., Consulting Engineers, of Boston, in a paper in the "Engineering News Record" of July 2, 1936, would indicate that such accusations were ungrounded.

Stearns, in his report published as House Document No. 775 of 1894, mentioned that investigations as early as 1878 showed that the height of the ground water in the Back Bay section of Boston was nearly level at about grade 7.7 Boston city base, and that, after the construction of the Boston Main Drainage Works, another investigation in 1885 showed that the ground water table was at practically this same level. The investigations by Snow and the building department of the city of Boston would appear to verify Stearns' statements. According to the information presented by Snow the deterioration in piles under some of the buildings was most pronounced in those sections shown on the following map (Fig. 20), located close to a deep sewer in the area under consideration. Because of this relationship a dam was constructed in the sewer which raised the level of the sewage to elevation 5 (Boston city base). Observations of the level of the water in wells throughout the district showed that the ground water table began to rise after the dam was constructed, and that all wells in the area showed the effect of the construction of the dam in this sewer. When the sewers were drained the ground water table was again lowered. In view of these observations it would appear to be safe to assume that the construction of the Charles River Basin has in no way unfavorably affected the ground water conditions in the Back Bay section of Boston. The following diagram (Fig. 21) shows the behavior of ground water in the vicinity of Copley Square as observed by X. Henry Goodnough, Inc., Consulting Engineers. There is also presented a photograph (Fig. 22) showing the condition of a pile removed from the foundation of the Boston Public Library.

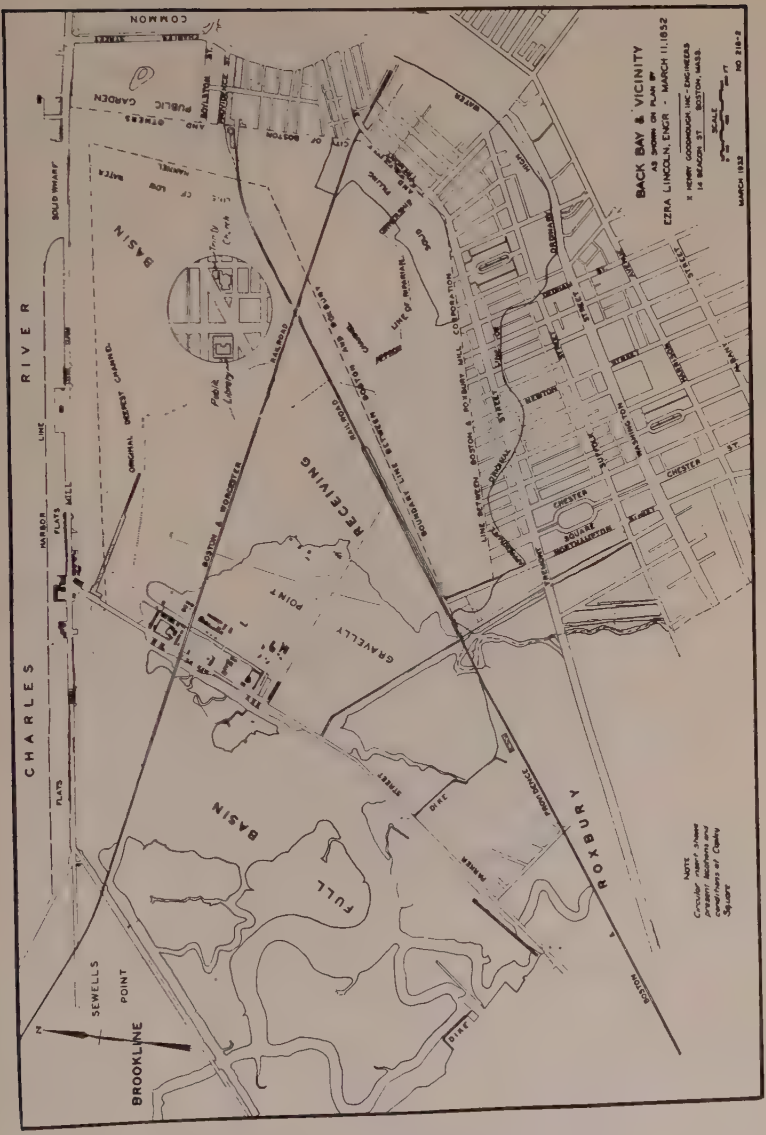


Fig. 20. — Site of Ground Water Studies in Back Bay Section of Boston

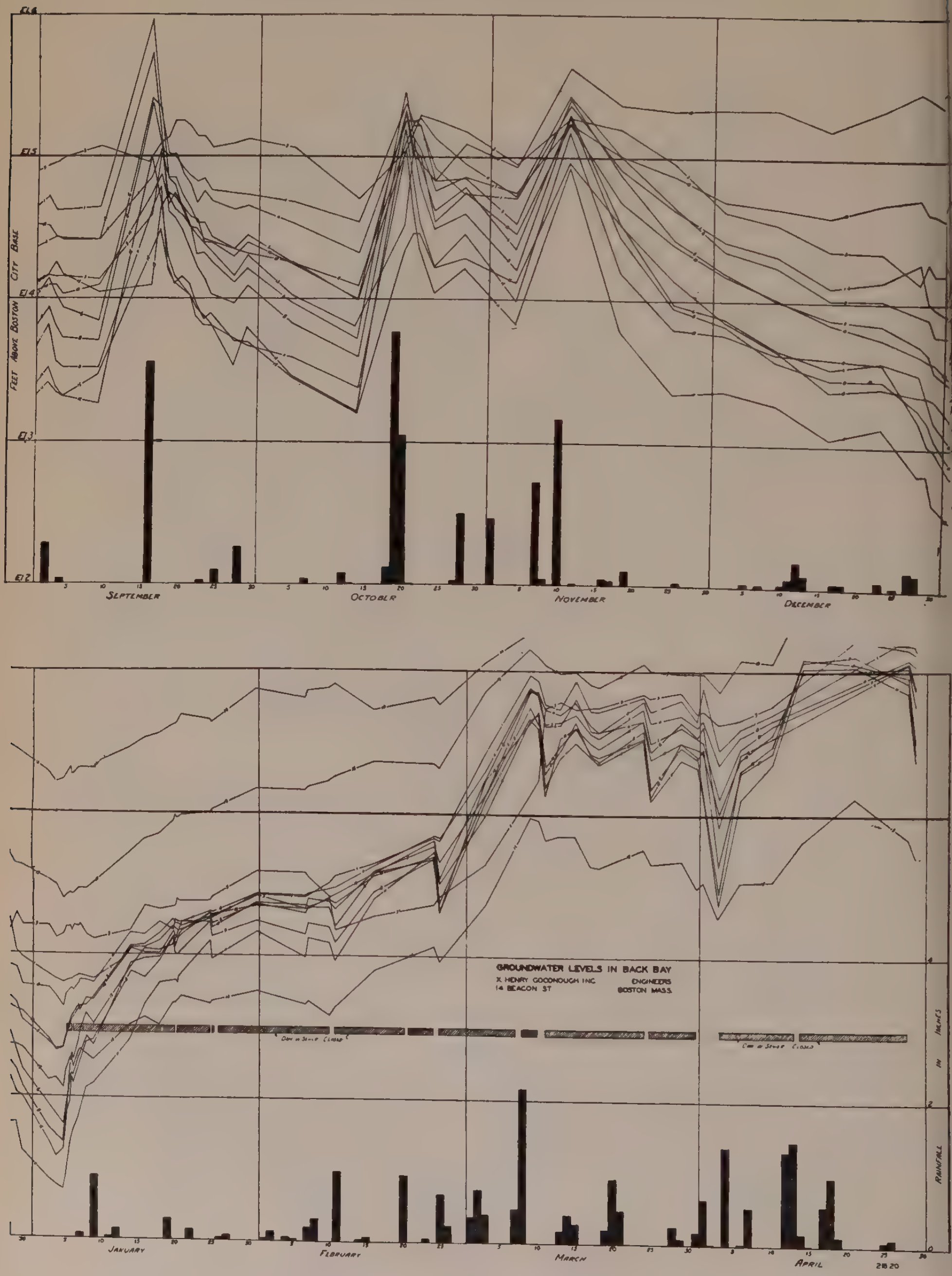


FIG. 21. — GROUND WATER ELEVATIONS IN BACK BAY SECTION OF BOSTON

Taking of Water from Charles River Basin for Fire Protection and Cooling and Condensing Purposes

Under the provisions of the General Laws, chapter 92, sections 76A to 76E, the Metropolitan District Commission may grant to any city or town bordering the Charles River Basin a permit to take water from the basin for purposes of fire protection and for sale to manufacturing establishments within its limits for cooling and condensing purposes. Such permit shall state the maximum amount of water to be drawn from the basin, and the place and manner of taking said water, and of its return, except for the purpose of fire protection, to the basin, and shall be granted upon the condition that water be supplied only to such manufacturers as can use it in a system of closed pipes without opening at any point within their premises, and that no oil, refuse or other substances which would be harmful to the water in the basin shall be added before its return. No such permit shall be granted unless

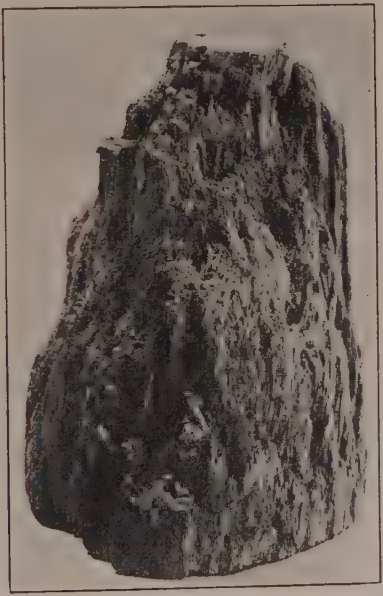


Fig. 22. — Photograph of Pile Head taken from Foundation of Boston Public Library

approved as to form by the Department of Public Health, and no construction shall be commenced or carried out under such permit until all plans and specifications have been submitted and approved by said Department. Upon violation of any condition of the permit, or if, in the opinion of the Metropolitan District Commission, the use of water impairs its quality or reduces the quantity of water in the basin, the Metropolitan District Commission shall revoke the permit.

The first municipality to avail itself of this legislation which was enacted in 1928 was the city of Cambridge, which requested a permit in July, 1938, for the purpose of supplying the proposed new office building of Lever Brothers Company, on Memorial Drive, with water from the basin for cooling purposes in conjunction with the air-conditioning system. This permit was granted by the Metropolitan District Commission, after approval as to form by the Department of Public Health, under date of August 15, 1938, but approval of plans and specifications has not as yet been requested of the Department of Public Health.

Summary

The early predictions that the Charles River Basin would afford a ". . . magnificent opportunity at comparatively small expense for replacing unsightly tidal mud flats and unclean muddy shores . . ."; that the construction of this basin probably would result in a "large increase in valuation of the marginal lands"; and that there would be ". . . lessened expense for development of . . . park lands upon the margin of Charles River . . ." would appear to have come true. There have been ". . . improved sanitary conditions . . . by lowering the extreme flood level", and decided improvement has resulted from preventing "the uncovering of large areas of foul smelling and unsightly mud flats. . . ."

Records available to the Department of Public Health show that there has been practically a complete absence of malaria in the Charles River Valley since the basin was constructed, but information is not available to prove that this condition was brought about by the construction of the basin. There has been, however, a "lessening of the mosquito pest" by preventing the flooding of marsh land in Brighton, Watertown and Newton. The construction of the basin also has improved conditions for navigation "by providing a constant water level", and there has been some gain in economy of power because of "generous supply of fresh water for . . . condensation made available to . . . steam plants. . . ."

It also has proven to be true that —

> . . . The construction of a dam with a proper system of locks . . . will . . . rather facilitate . . . than hinder this traffic. The formation of ice in the winter will be a possible objection. . . .

The special committee prediction that —

> A comparatively still body of fresh water with animal and plant growths will dispose of a considerable amount of sewage admitted from time to time, and will tend to purify itself even if no more fresh water is added.

has proven to be true, even though the amount of fresh water entering this basin has at times been less than predicted by the designing engineers. It probably is also true that these engineers did not consider the extent to which the basin would be used for recreational purposes, especially its use for bathing. The Charles River Basin has not reached the point where the oxygen content has been depleted to such an extent as to result in a nuisance, but the overflow of sewage into this basin makes the basin unsafe at times for bathing. This condition is contrary to the expectations of the special committee when they stated —

> . . . As this basin is to be used for park purposes, it is essential that the condition of the water should not only be harmless to health, but also that there should be no suggestion of sewage; that the waters be as pure as reasonably possible, and thus both the factor of sanitary safety and the enjoyment of the water park be increased. . . .

Because of the large amount of water diverted from the Charles River Valley above the Charles River Basin for water supply and mill purposes, it is important that additional facilities be provided for diverting all sanitary sewage out of this basin.

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THE ENGINEERING FEATURES OF THE CONCHAS DAM PROJECT

By James H. Stratton*

(Presented at a meeting of the Boston Society of Civil Engineers held September 28, 1938)

The Conchas Dam project was initiated under the Emergency Relief Act of 1935, and later adopted by Congress in the Flood Control Act of June, 1936, to provide flood control, irrigation and municipal water supply benefits. The site is on the South Canadian River a short distance below its confluence with the Conchas River, in the northeastern section of New Mexico, about 170 miles east of Albuquerque, New Mexico. The Conchas Dam project had previously been investigated in the "308" studies of the Arkansas Basin by the Corps of Engineers. The design and construction were assigned to the Corps of Engineers and the Conchas District was established on August 1, 1935, with temporary offices in Tucumcari, New Mexico, about 60 miles from the project. Investigations and surveys for the project design were initiated immediately.

Coincident with the project studies and investigations, steps were taken to provide housing facilities for the administrative, engineering and construction organization at the site. The completed construction town includes living quarters for 125 families and 1,400 workers, offices, stores, shops, warehouses, gravel-surfaced streets and utility installations. These facilities, although of a temporary nature, provide services comparable to those of a modern city. More than 2,500 relief workers were employed on this phase of construction.

Project Description

The Conchas Dam project will consist of a concrete main dam and contiguous earth wing dams; earth dikes flanking a concrete emergency spillway; a large earth dike, irrigation headworks; and an earth saddle dam. The project will require 830,000 cubic yards of concrete, 2,900,000 cubic yards of earth fill, and 786,000 cubic yards of rock fill. The irrigation and water supply distribution works are not a part of the present project.

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The main dam, a concrete gravity structure located in the canyon of the South Canadian River, has a maximum height of 235 feet and a crest length of 1,250 feet, with an overflow section 340 feet long. Gate-controlled outlets are provided for flood regulation, low water flow regulation, and to enable drainage of the reservoir. Outlets for future water supply and electric power generation are also provided. The wing dams contiguous to the main dam will extend north 1,000 feet and southeast 4,000 feet, approximately.

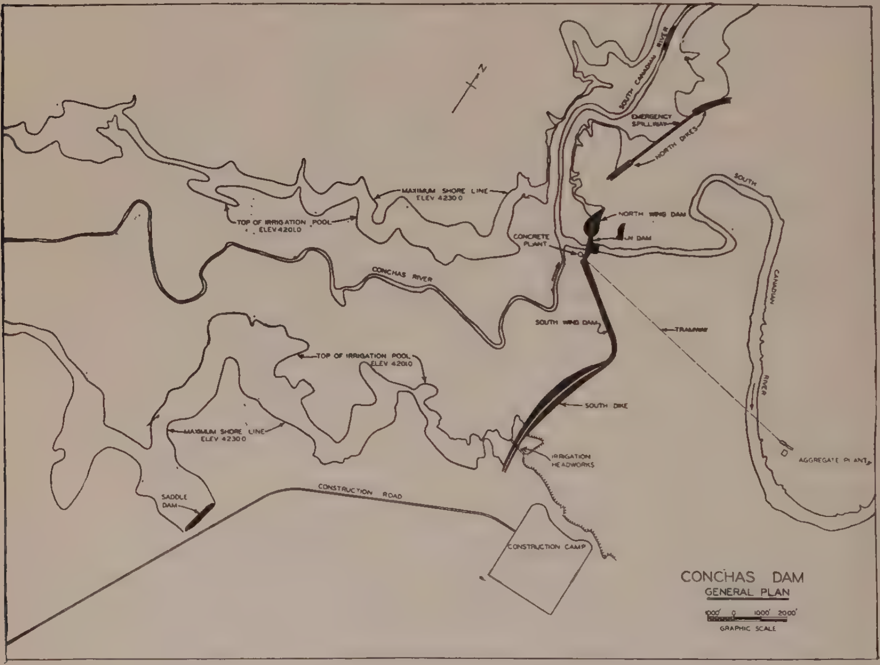


Fig. 1. — General Plan of Conchas Dam

The south dike, of earth and rock fill, approximately 96 feet high and 6,400 feet long, is contiguous to the south wing dam of the main dam. The principal feature of the irrigation headworks at the south end of this dike is a concrete-lined tunnel approximately 700 feet long.

The 3,000-foot concrete ogee emergency spillway of 40-foot maximum height is located in a low saddle on the left bank of the South Canadian River, and is flanked by earth dikes extending to high ground. The dike contiguous to the south end of the spillway is 1,400 feet long and has a maximum height of 30 feet; that on the opposite flank is 1,150 feet long and has a maximum height of 20 feet. The earth and rock fill saddle dam three miles south of the main dam is 1,400 feet long with a maximum height of 4 feet.

Hydrology of the South Canadian Watershed

The South Canadian River rises in the Sangre de Cristo Mountains near Raton, New Mexico, and flows generally south to the Conchas Dam site. The mountainous headwater area, varying in elevation from 6,500 to 11,500 m. s. l., comprises about 46 per cent of the drainage area, the plateau area about 39 per cent, and the plains area in which the dam is located, the remainder. The designations applied to the watershed area are descriptive of the general character of the topography of the 7,250 square miles of drainage area above the dam site. The general region is notable for a high percentage of sunshine, high rate of evaporation, excessive wind movement in the spring months, and local thunderstorms of high intensity of precipitation in the spring, summer and fall. Precipitation varies from a mean annual average of 14.5 inches in the vicinity of the dam site to 21.8 inches in the mountainous area. The recorded monthly precipitation at the vicinity of the dam site varies from a maximum of 8.78 inches to a minimum of zero. Mean monthly temperatures vary from 35.8° F. in January to 77.5° F. in July. Evaporation records at Elephant Butte Dam and at the Agricultural College Station at Las Vegas, New Mexico, indicate a mean annual average of 98.4 inches and 91.0 inches, respectively.

Rainfall and run-off records, themselves deficient, indicate, as one might expect, that run-off is dependent largely on rainfall intensity, degree of saturation of the soil, and the available depression storage, and has varied for the mountainous region from 57.5 per cent for the 1904 flood (estimated peak discharge of 280,000 c. f. s. at the dam site) to 13.6 per cent for the 1914 flood, the largest floods of record. For the plateau region, the run-off percentages were 35.7 and 11.8, respectively, for the same floods. Annual run-off at the Conchas Dam site ranges from a minimum of 0.085 inch to a maximum of 1.74 inches, with a mean annual average of 0.54 inch. Existing irrigation developments above the dam site with a total storage capacity of 267,800 acre-feet, considerably reduce the spring run-off.

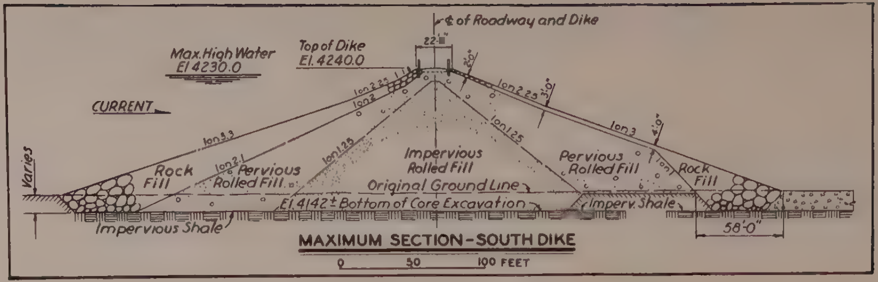
Recourse was had to all records of flood occurrence in the Southwestern States to establish the basis for design capacity of the spillways to insure the safety of the structures. The meteorological and hydrological studies disclosed that possible maximum flooding with high peak discharge would probably be produced by storms of only two or three days' duration, those of greater duration generally producing floods of greater volume without corresponding increase in peak discharge. The selected spillway design flood was constructed by transposing the 1914 storm, the greatest of record in the general region, to a critical position over the drainage area above the dam site. To insure a high peak discharge, run-off factors of 72 per cent for the mountainous area and 45 per cent for the plateau and plains areas were assigned, and the flood hydrograph was shaped to conform to the hydrograph of the 1904 flood. It was also assumed that the irrigation dams above the site of less than adequate design would fail and add a large increment to the peak discharge. Capacity well in excess of the spillway design flood with a peak discharge of 582,000 c. f. s. is provided in the main dam overflow spillway and the emergency spillway.

Mass flow studies disclose an estimated mean annual draft of 140,000 acre-feet as available for irrigation purposes, for which there is reserved 300,000 acre-feet of reservoir capacity. Provision is made for the later installation of automatic crest gates in the overflow spillway of the main dam to increase the irrigation storage to 400,000 acre-feet. Below the irrigation pool will lie 100,000 acre-feet of storage, 60,000 acre-feet of which are available for future water supply and for low water flow regulation.

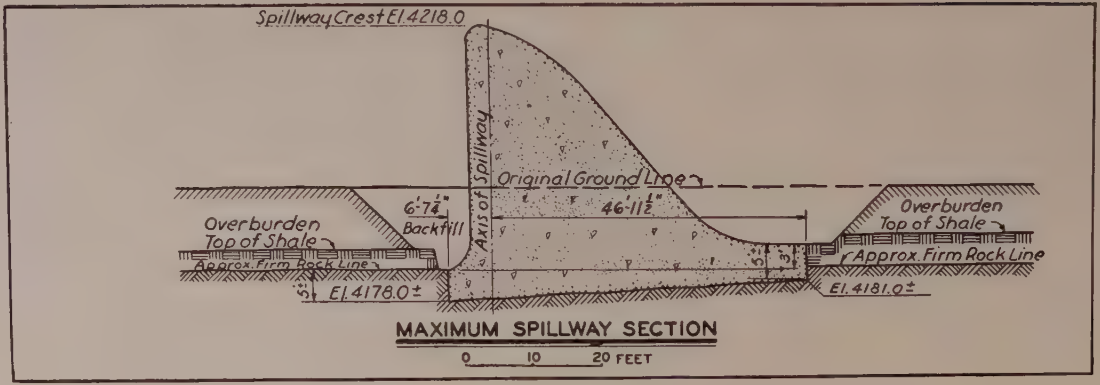
Two hundred thousand acre-feet of reservoir storage above the overflow crest (El. 4,201) in the main dam will regulate flood flows up to the elevation of the emergency spillway crest (El. 4,218) within channel capacity below the dam, fully controlling all floods of record except that of 1904. Additional storage to effect a greater degree of flood control would be uneconomical. The crest gates when installed will effect an increase in the regulated outflows of the small floods, but will not have a marked effect on the outflows of large floods. The increased outflows induced by the crest gates will not exceed downstream channel capacity for floods which would be regulated within banks were there no crest gates installed.

GEOLOGY

The geologic formations at the Conchas Dam site are of sedimentary origin and consist largely of alternating layers of sandstone, shaly



MAXIMUM SECTION-SOUTH DIKE



MAXIMUM SPILLWAY SECTION

Fig. 2. — Conchas Dam — South Dike and Emergency Spillway

sandstone, shale and sandy shale. There is a marked lack of uniformity in the formations, both horizontally and vertically. For convenience, the outcroppings at the dam site have been named, beginning with the lowest and oldest, artesian sandstone formation, which includes a low stratum of red shale; the next overlying, the pink shaly sandstone formation; and then, in order, above the pink shaly sandstone, the red shale, the canyon sandstone, variegated shale and townsite sandstone formations. The canyon sandstone is the uppermost formation at the deep gorge where the main concrete dam is being constructed. It has a depth of 80 feet in the right abutment and 20 feet in the left abutment at the site. This formation is about the best of outcropping formations, and will provide adequate foundation despite lenses of shale and somewhat extensive jointing. Underlying the canyon sandstone is the red shale formation which has a thickness of 50 feet in the right abutment and 80 feet in the left abutment. This shale disintegrates when exposed to the air; although compact and dense it is fissured with minor slickenside surfaces and has some jointing. As an abutment formation it presents a difficult problem. Underlying the red shale is the pink shaly sandstone which outcrops in the abutments and the river terraces, where it serves as foundation for the abutment monoliths. This formation is markedly discontinuous and ranges from about the best to worst foundation rock at the site. The existence of clay and shale seams and lenses accounts for the poor character of this formation, and where they are absent there results an acceptable foundation. Outcropping in the river bed and underlying the pink shaly sandstone there is an artesian sandstone, grayish in color, which has a character well described by its name. Separated by a stratum of red shale of fair continuity there is a still lower artesian formation. The upper artesian sandstone will serve as foundation for the river monoliths. No more can be said for the character of this artesian sandstone than was said for the pink shaly formation, since it ranges from soft clay or shale to a fairly dense but porous sandstone. The variegated shale and townsite sandstone formations which outcrop at the site of the south dike are of about the same general character as the formations at the site of the main dam. Space limitation precludes further discussion of the geologic and structural characteristics of the abutment and foundation formations at Conchas Dam.

Design and Construction Problems

No unusual problems have arisen in the design and construction of the emergency spillway, the dikes, wing dams and the large south dike.

Satisfactory aggregates for concrete construction are found in low benches along the river two miles below the site of the dam. Close to the earth structures there is available a wide range of material, from adobe clay in the flats below the high mesas to sandy silts close to the mesa escarpments, which are suitable for use in the impervious sections of the dikes and earth dams. Sands and gravels in near-by benches are excellent for the pervious shells of the earth structures. Suitable sandstone quarries are available in abundance and a number have been opened to provide riprap and rock fill.

An interesting feature in the construction of earth structures has been the extent of pre-wetting of earth fill in the borrow pits. The deficiency of water in the winter and early spring when the streams are totally dry would seriously handicap construction if water were not stored so as to be available during the drought periods. Tank and reservoir storage for other than concrete mixing and curing is precluded by the cost of storing the tremendous quantities required. Consideration was given to the use of artesian water, but it was determined that the wells would have to be of great depth, and that they would be of questionable reliability and their cost excessive. The pre-wetting of borrow areas well in advance of their use proved a happy solution. Economy in pre-wetting results largely from the fact that special storage reservoirs for dry season earth dam construction are unnecessary. The wetted borrow pits are virtually subterranean reservoirs with a decided advantage over surface reservoirs because of their low evaporation losses. Further, the material in the wetted pits is processed for optimum compaction well in advance of operations, thereby facilitating placement and avoiding the usual erratic results and the difficulties and complications in wetting the material when being placed.

MAIN DAM

Earth, rock fill or masonry gravity construction for the main structure in the deep canyon are all feasible, and their cost would be about the same because of the diversion tunnel requirements for an earth or rock-fill dam. The concrete gravity section was selected largely because of the lesser likelihood of damage by floods during construction. Other factors, such as artesian flow in the foundation, influenced this decision. This selection proved a wise one. Two major floods have occurred since the start of the main dam construction, the larger having a discharge of close to 100,000 cubic feet per second, the greatest since 1914 and the fifth of record.

In the design of the concrete gravity section, allowance was made for uplift, varying as a straight line from full hydrostatic head at the heel to artesian pressure elevation at the toe of the bulkhead sections, and to tail-water elevation at the toe of the overflow sections. The pressure was assumed as effective over two thirds of the area of the base. An allowance of 0.10 g. was made for earthquake, and the criteria established that the resultant pressure should lie within the limits of the middle third. Because of the weak shale laminations and lenses in the sandstone foundation, failure by shearing in the foundation rather than by sliding of the dam on the foundation appeared much more likely. Accordingly, the section of the main dam was designed to avoid tensile stresses at the heel, which might be transmitted to the foundation through the bonding action of the concrete, thereby weakening its shearing resistance. Shearing of the foundation would, of course, also vitiate the upstream grout curtain as a means of reducing seepage, induce increased uplift, and further the danger of failure. As an added

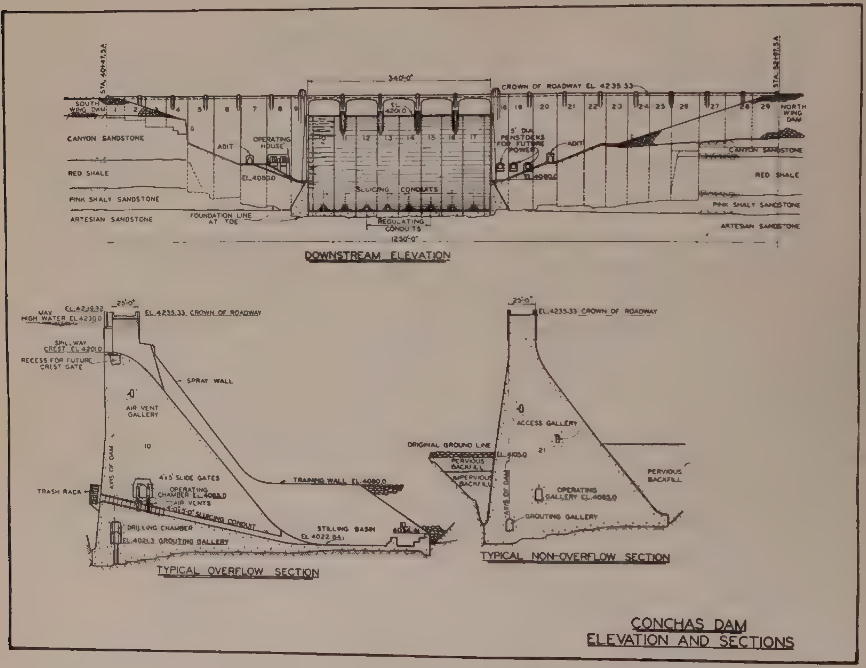


FIG. 3. — CONCHAS DAM — ELEVATION AND SECTIONS OF THE MAIN DAM

precaution against sliding and shear in the foundation, the monolith foundations in the artesian and pink shaly sandstone were stepped downward in an upstream direction with an average differential of 15 feet between toe and heel. A minimum thickness of 10 feet of rock was maintained at the toe of the concrete bulkhead section, the concrete being placed against a channeled face at the toe in the non-overflow section. In the overflow section, the monoliths are backed up by the stilling basin floor which is securely anchored to the artesian sandstone. Pipes on 4-foot centers, inclined for maximum intersection of the vertical joint system, are installed in the fillet at the heel of the dam for foundation drilling and stage grouting of a curtain cut-off to impermeable red shale at a depth of approximately 40 feet below the minimum elevation of the foundation. An additional curtain may be grouted approximately 20 feet downstream of the heel curtain through pipes installed at 5-foot centers in a grouting gallery, if found necessary. A second gallery 27 feet downstream of the first provides for drainage from 10-inch pipes set at approximately 15-foot intervals, which bleed 8-inch holes drilled 30 feet into the foundation. The foundation drain holes and pipes are interconnected by half tile drains encased in gravel laid on the foundation. Water seeping into the foundation excavation through the joints of the artesian sandstone required pumping from

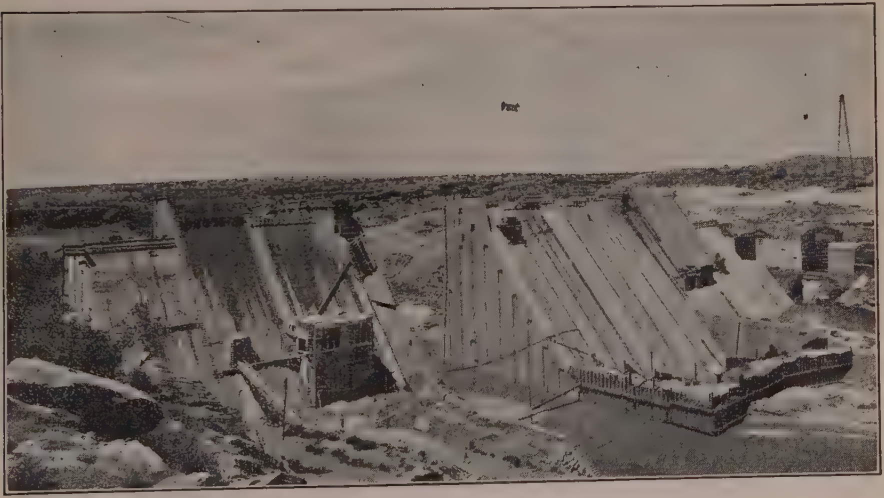


FIG. 4. — CONCHAS DAM — MAIN DAM

sumps, gravel drains and riser pipes which tap leaking joints to secure dry foundations for concrete placement. A majority of the temporary drains were grouted, only a few near the toe being left as telltales. The drainage gallery will serve as a collector for these remaining auxiliary foundation drains. Uplift pressure pipes are installed to facilitate the determination of the hydrostatic pressures in the foundation.

Each monolith foundation is test drilled to establish its suitability, and typical foundation specimens are tested to determine its shearing resistance and compressive strength. Shearing values of 99 saturated specimens range from 424 to 2,319 pounds per square inch and average 943 under a normal load of 100 pounds per square inch. Occasional values as low as 350 pounds per square inch are encountered and such material is removed. Forty-one compression tests varied from 1,067 pounds per square inch to 9,717 pounds per square inch and averaged 3,990 pounds per square inch. Shearing values of dry specimens range 20 per cent to 30 per cent higher. The computed maximum shearing stress in the foundation is 250 pounds per square inch. Thirty-inch inspection holes are to be drilled later through 36-inch pipes resting on the foundation with access from the grouting gallery to enable inspection of the foundation.

Model studies conducted at the United States Waterways Experiment Station at Vicksburg disclosed that a relatively short stilling basin, with a horizontal apron located at the natural bedrock elevation, and having one row of baffle blocks and a stepped end-sill, would dissipate satisfactorily the excess energy in the water flowing over the spillway or through the conduits for the complete range of discharge expected. From a standpoint of design criteria, that is, velocities, scour and stability of flow, this scheme proved to be decidedly superior to others tested. From a standpoint of cost, it was considerably cheaper. The dam is provided with six sluicing conduits 4 feet by 5 feet, controlled by vertical slide gates set in tandem. The primary purpose of these conduits is for flood regulation and the draining of the reservoir. In addition, two regulating conduits, controlled by 48-inch needle valves and emergency butterfly valves, are provided to maintain the required flow in the river. The gates are controlled from a gallery in the dam.

Concrete Construction

The concrete aggregates are transported from the washing plant at the pit to the batching plant at the right abutment of the main dam, a distance of nearly two miles, by aerial tramway. Gravel up to 6-inch size is being used in three size separations; the fine aggregate is batched in two separations. Cement meeting moderate low heat specifications is shipped in bulk by rail to Newkirk and transported by truck a distance of 30 miles to storage silos at the batching plant. Concrete placement is by twin cableways leading to a common tail tower. Monoliths range from 40 to 50 feet in width and are being constructed in 5-foot lifts. Since lift joints are potential planes of weakness, both for sliding and the penetration of water which may exert uplift, precautions were taken to obviate poor bonding surfaces. These included sloping the joints upward in a downstream direction and cleaning them with a high pressure air and water jet shortly after the initial set has taken place and again just prior to placing the next lift.

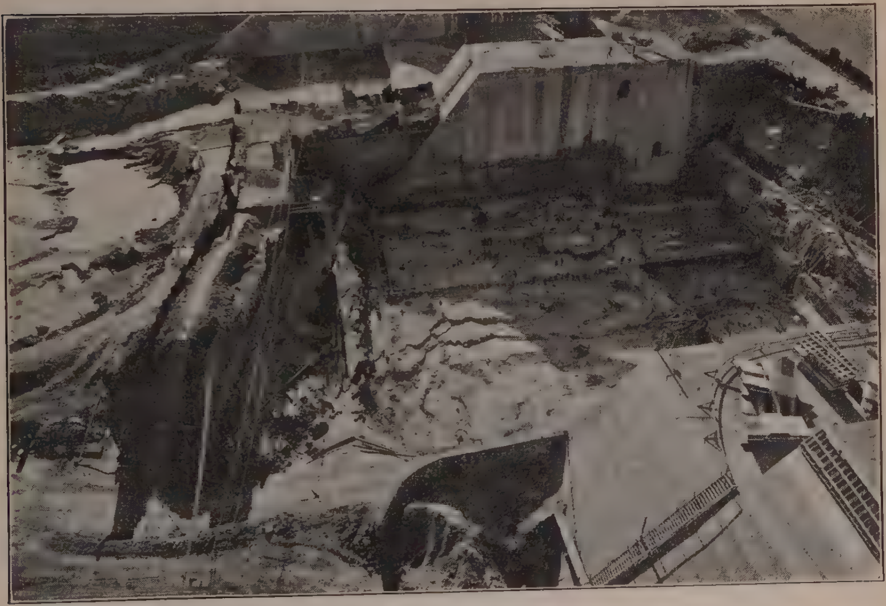


Fig. 5. — Conchas Dam — Cofferdam at Main Dam

Except in the abutment monoliths (Nos. 5 and 26), transverse joints are not provided. Monoliths are keyed together, but the joints are painted with a bituminous compound to prevent bonding. Copper water stops in bituminous filled wells are provided to prevent joint leakage from the reservoir. Re-entrant corners are avoided, and such provisions as heavy fillets at the heel and toe are designed to prevent dangerous stress concentrations and to minimize cracking of the concrete. Temperature, strain and settlement observations are being made as construction proceeds. Cracking in the concrete has occurred in monoliths Nos. 6 and 21. The observation data have been invaluable in analyzing the cause and the prevention of cracking. Mats of reinforcing steel were placed over the cracks as they appeared and have served thus far to prevent the cracks from extending into the overlying monolith lifts. Reduction in cement content will reduce the tendency toward further cracking. The final results of the analysis and the effectiveness of the measures taken to prevent further cracking must await the passage and test of time.

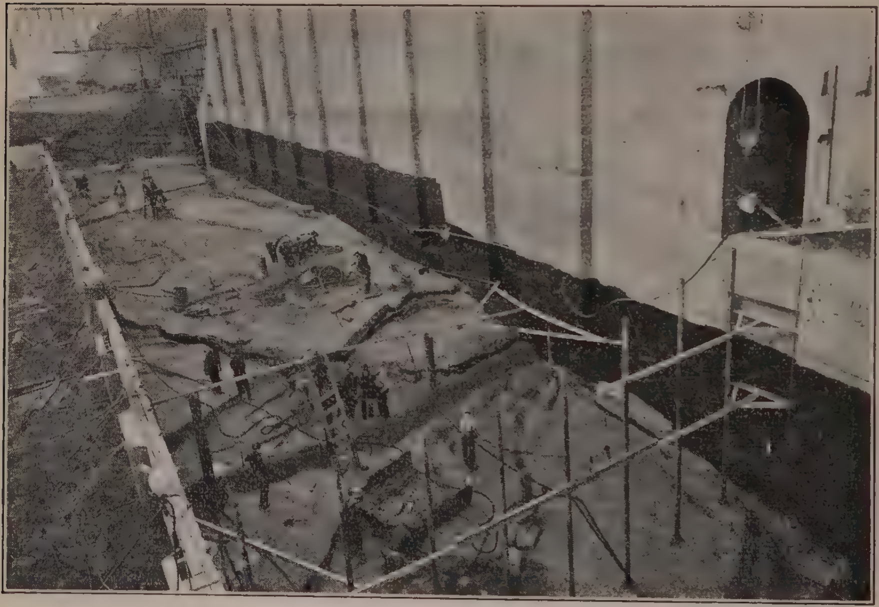


Fig. 6. — Conchas Dam — Foundation of Monolith No. 14. View Downstream

Careful control of the aggregates and the mix during construction has resulted in large economies in cement. The outer portion of the dam, that is, the outer 10 feet approximately, is being constructed of 4-bag concrete to provide a dense and durable shell to the body of the structure which is constructed of 3-bag concrete. The outer shell of dense concrete is, of course, being placed monolithically with the concrete mass for which it is a facing. Tests of 8-inch, twenty-eight day cylinders of Class "C" concrete which forms the interior mass of the main dam, having an average cement content of 3 bags per cubic yard and 7.8 gallons of water per bag, show an average strength of 2,715 pounds per square inch. Extreme strength ranges from 2,200 to 3,300 pounds per square inch. Concrete is cured fourteen days by being kept continuously wet. Wet sand is used for curing where the slope of the surfaces permits. Because of the possible shortage of water for curing of concrete in drought seasons, various bituminous and clear surface coatings were investigated to determine their effectiveness as curing compounds. The conclusion reached led to the specification requirement that the contractor provide adequate storage of water for concrete curing in prolonged periods of drought, and that he develop artesian wells for available supply if his stored water proved inadequate. Since the artesian water stains a deep rust color, it has been fortunate, from an esthetic viewpoint, that its use for curing has not been extensively necessary.

The winter climate in the vicinity of Conchas Dam is not unduly severe; however, occasional temperatures below zero Fahrenheit are to be expected. In order to maintain the desired concrete schedule, it was necessary to continue concrete operations throughout the winter. During the cold weather mixing water was heated to about 180° F., but no heating of aggregate was found to be necessary. After the concrete had been placed in the forms and the surface jetted, the top of the monolith was covered with a layer of sand about 4 inches thick. This sand was thoroughly wetted and covered with tarpaulins. Side forms provided sufficient protection to keep the concrete from freezing, and were left in place for a period of five days. Periodic temperature readings taken at various points on the concrete indicated that this method provided adequate winter protection especially.

Main Dam Abutments

Extensive examination of the foundation and abutments by drilling, test pitting and large scale excavation operations prior to the completion of the design disclosed that the abutments would be of questionable stability after excavation of the talus to the vertical neat faces, which would leave unsupported shale 50 feet deep in the right abutment and 70 feet deep in the left abutment until such time as the restraining abutment monoliths were constructed. For the left abutment, consideration was given to terminating the concrete section of the dam at the abutment, sloping the abutment to give it stability, and continuing beyond the abutment monolith to high ground with an earth wing dam with the fill wrapped around the terminal concrete monoliths. This procedure was estimated to be very expensive, and it was decided to excavate this abutment to a vertical face, speed the completion of the supporting deep canyon abutment monolith (No. 23), and to continue the concrete section beyond the abutment by monoliths (Nos. 24 to 29, inclusive) founded on the canyon sandstone (caprock). To insure stability of the vertical shale face, 1 foot or more of shale outside the final neat face was to be left for stripping just prior to concreting the abutting monolith. To prevent disintegration of the shale through dehydration, all faces were to be painted with a tested sealing compound. Extensive testing of various bituminous and asphaltic compounds on large exposed panels in the shale face of the left abutment led to the selection of one which gave fair promise of providing adequate sealing against dehydration. Unfortunately, expectations did not materialize, and the left abutment failed before excavation was quite complete. Failure of the shale appears to have been brought about through the drying out of

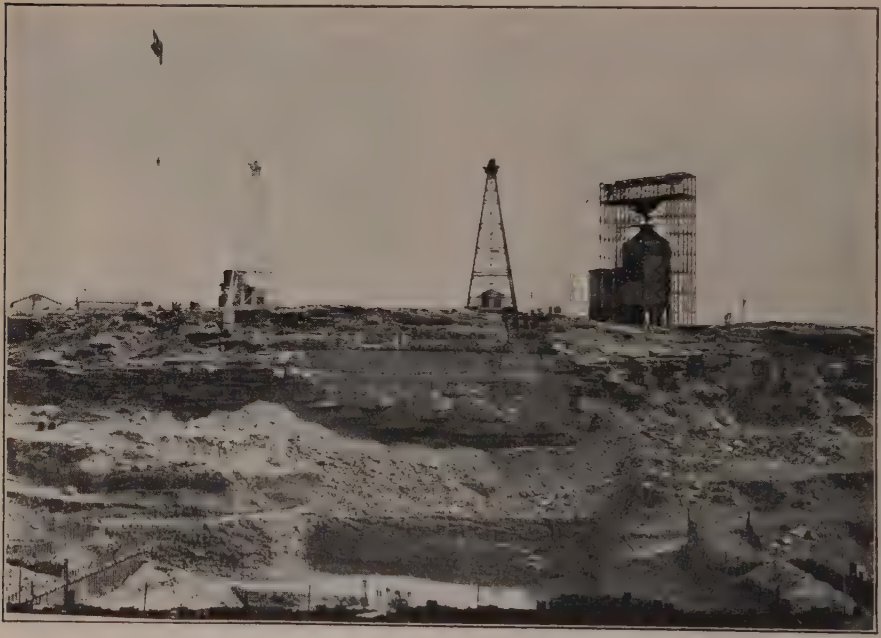


FIG. 7. — CONCHAS DAM — VIEW OF THE RIGHT ABUTMENT

the exposed face, and by the existence of many slickensides and joint planes in the shale, and was evidenced by the spalling and popping of large blocks of disintegrated shale. The protective coating apparently failed in its purpose, and as excavation proceeded and stress conditions exceeded safe limits, localized failures occurred in the dehydrated faces. Opening of old joints and the forming of new cracks in the overlying caprock as a result of failure of the shale further evidenced the impracticability of proceeding further.

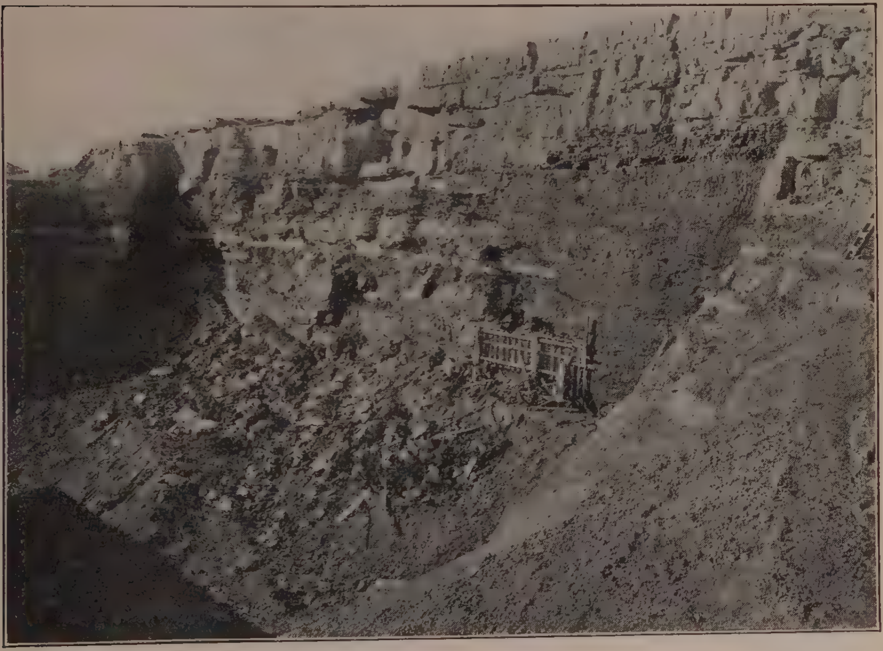


FIG. 8. — CONCHAS DAM — LEFT ABUTMENT, MAIN DAM, SHOWING DAMAGE TO ABUTMENT FACE CAUSED BY SHALE DISINTEGRATION

Reconsideration was given to the original plan and to other alternatives suggested after the shale failure in the abutment. It was decided that a supporting monolith (No. 26) should be constructed by shaft excavation prior to the abutment excavation. The revised design provides for the excavation of a slot of the base dimension of monolith No. 26 in the left abutment approximately 110 feet from the escarpment face in a series of six shafts braced and lagged to prevent failure, and the completion of monolith No. 26 successively therein up to the top of the caprock in six columnar sections. Above the caprock, monolith No. 26 will be completed monolithically. The remaining sandstone and shale riverward of monolith No. 26 will be excavated after completion of concreting of monolith No. 26. The monoliths intervening between it and those in the canyon already completed will be placed thereafter. The result will be a continuous deep concrete section from monolith No. 5 to No. 26, inclusive, instead of from monolith No. 5 to No. 23, inclusive, as in the initial design.

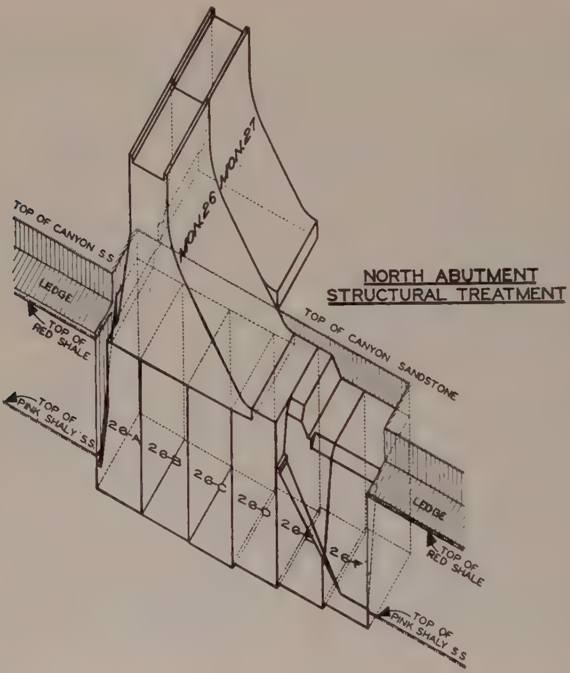


FIG. 9. — CONCHAS DAM — ISOMETRIC VIEW OF LEFT ABUTMENT, MONOLITHS

The five transverse joints in monolith No. 26, formed by constructing it in six columnar sections, are provided with horizontal keys and will be grouted after the concrete has cooled. Pipes are installed in this monolith for circulation of a cooling medium to expedite shrinkage of the concrete and permit early grouting of the transverse joints. The portion of the monolith above the caprock will be placed monolithically above the six columnar sections, which will be consolidated by grouting.

RIGHT ABUTMENT

Instability of the right abutment, as in the case of the left abutment, is of concern after the removal of the supporting talus until such time as the abutment monolith (No. 5) is erected. The consequences of disintegration and failure of the 50-foot stratum of shale in this abutment would be more serious, however, because of the danger of subsequent collapse of the 80-foot stratum of overlying sandstone. Examination disclosed considerable jointing of the caprock in this abutment, which, although discontinuous, is interrupted by lenses and seams of weaker shale and shaly sandstone. As insurance against possible failure of the overlying capstone by parting at the joint planes after the talus slope was removed, the contractor elected to underpin it. To this end, eleven shafts were excavated under the rim of the caprock through the shale to good foundation, and re-enforced concrete columns 5 feet by 5 feet on 15-foot centers were constructed to provide the desired support. The columns are cross-connected below the caprock by heavy re-enforced concrete girders to provide continuous support for the caprock.

As soon as the underpinning operation was sufficiently advanced to obviate danger of local failure, excavation for monolith No. 5 was commenced, and as the talus was removed, re-enforced concrete panels, 2½ feet thick by 8 feet in height designed as beams, were constructed progressively from top to bottom between the columns and keyed thereto. The girders and the columns support the overlying caprock, and, with the panels, support and protect the shale abutment. To provide additional support for the shale face, and to insure against failure of the columns, they were braced with heavy timber trusses against the south face of monolith No. 6 which had been previously erected to a height above the elevation of the bottom of the caprock (El. 4,120). The columns are supported on the sides by the shale, the panel beams, and in a direction opposite the thrust from the shale by the temporary bracing, hence no bending was considered in their design. As a further precaution, the contractor was permitted to construct monolith No. 5 in three sections up to the elevation of the bottom of the caprock; the transverse joints are provided with keys and will be grouted to insure monolithic action. The slope of the transverse joints was determined by locating them approximately on the first principal stress trajectory, that is, line of zero shear for the condition of full reservoir. Artificial cooling of monolith No. 5 will accelerate the shrinkage of the concrete and will permit early grouting of the transverse joints. Monolith No. 5 will be constructed without transverse joints above elevation 4,124.

The entire operation was a progressive one; columns were constructed successively from upstream to downstream, excavation and the cross girders, panel beams and monolith No. 5 construction following as soon as feasible. This procedure obviated delays and permitted the initiation of the construction and the completion of the upstream third section of monolith No. 5 to the base of the caprock before excavation had been commenced in the downstream third. An interesting development arose from the fact that the elevations of some of the column footings were higher than that found necessary for monolith No. 5. Since the supporting power of the columns would be destroyed if excavation adjacent to them were taken below their bases, it was decided to leave a temporary berm extending into monolith No. 5 along the high column footings, the berm to be removed later through a shaft in the overlying concrete of monolith No. 5, after it had been brought up a distance above the base of the columns. To insure against bonding of the concrete to the rock berm, the latter was insulated with adobe bricks and roofing paper. After the removal of the berm through a shaft in the overlying

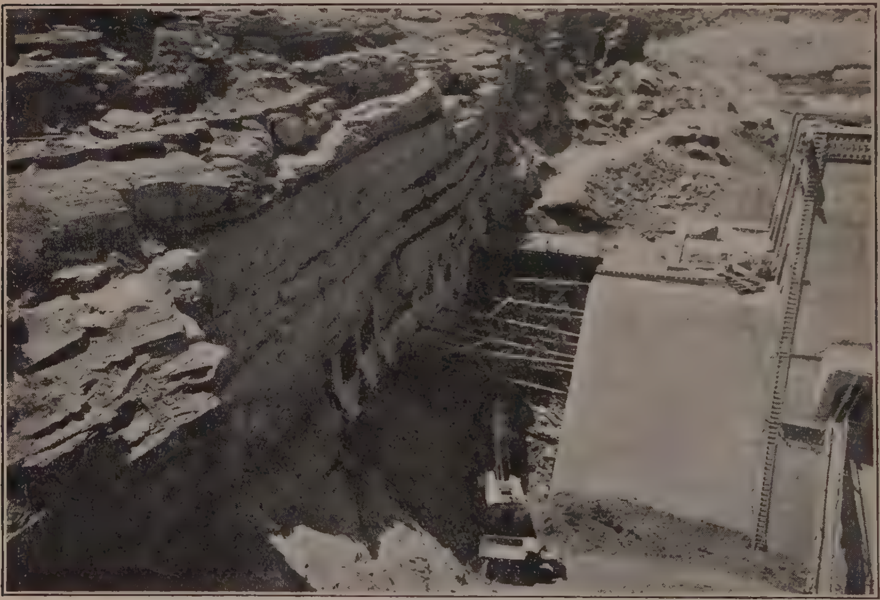


FIG. 10. — CONCHAS DAM — RIGHT ABUTMENT, MAIN DAM, SHOWING PARTIALLY COMPLETED UNDERPINNING

concrete of monolith No. 5, the space will be filled with concrete by ramming and grouting.

Analysis of the loading on the capstone and the underlying shale of the monoliths on the left bank (Nos. 26 to 29, inclusive) indicated that settlements under empty reservoir loading would be about 0.34 foot at the heel and 0.10 foot at the toe, a differential of 0.24 foot. Under full reservoir, the differential settlement would be 0.12 foot at the heel and 0.28 foot at the toe, a differential of 0.16 foot. It was assumed in the settlement analysis that the 20-foot stratum of caprock at the left abutment would fracture and not spread the load, and that each condition of loading would obtain sufficiently long to fully consolidate the underlying shale, a manifest impossibility. These rigorous assumptions were made to develop the worst possible effects of the action rocking on the underlying shale of the monoliths founded on the caprock.

Other studies included the effect of key restraint between the monoliths founded in the deep canyon and those founded on the caprock, and the effect of their differential settlement and movement under various conditions of loading. It was concluded that massive keys between the high and low monoliths would be an asset rather than a detriment, although there was some difference of opinion on this conclusion.

Another problem which entered into consideration was the effect of water entering between the abutment monoliths and the abutment shale faces in the cracks opened by the shrinkage of the abutment monoliths. To insure against erosive seepage and the adverse effect of alternate wetting and drying of the shale, three vertical wells between the left abutment monolith (No. 26) and the shale face are provided. The upstream and downstream wells will be filled with bituminous sealing compound; these wells have pipes and returns for the passage of steam to liquefy the bituminous material to insure its effective functioning. The center well will be filled with Bentonite, the properties of which are well known. Three similar wells are provided between monolith No. 5 and the concrete supporting panels underlying the caprock rim in the right abutment. The two wells in this abutment having bituminous fillers are also provided with copper water stops. After the supporting columns and panels in the right abutment are fully cured, the space between them and the shale abutment face will be grouted. The shale in both abutments is protected against disintegration by sealing the faces with a selected bituminous compound immediately after stripping to a neat line.

Studies and tests were made of the consolidation characteristics and preconsolidation loads of the abutment shale, its compressive and shearing strength, its flow characteristics, the best form of protection against disintegration, and possible chemical or grout treatment or consolidation, to improve its strength and prolong its life under adverse conditions. Not all the tests led to satisfactory or conclusive results. Space limitation precludes discussion of these and many other interesting features of the investigation and design of the Conchas Dam project.

The Conchas Dam project is being constructed by the Corps of Engineers with Captain Hans Kramer, District Engineer, Conchas District, in direct charge. The Conchas District is in the Southwestern Division with headquarters at Little Rock, Arkansas. Colonel Eugene Reybold is Division Engineer.

When the project was initiated the Conchas District was under the Lower Mississippi Valley Division, with Brigadier General Harley B. Ferguson as Division Engineer.

The writer was Chief of the Engineering Division on the project from August 1, 1935, to May 15, 1937.

Acknowledgment is made to Capt. Hans Kramer and others on the project for their valuable assistance in the preparation of this paper.

OF GENERAL INTEREST

JOHN R. FREEMAN FUND SCHOLARS

By Charles T. Main, Chairman, John R. Freeman Fund Committee of the Boston Society of Civil Engineers

The establishment of funds by the late John R. Freeman, entrusted to three leading engineering societies for the purpose of advancing the science of hydraulic engineering by the award of scholarships, has made possible the fulfillment of the vision of the founder. This ideal is expressed in the letter from Mr. Freeman to the President and Directors of the Boston Society of Civil Engineers, dated March 19, 1925.

Mr. Freeman made these gifts to the Boston Society of Civil Engineers, the American Society of Mechanical Engineers, and the American Society of Civil Engineers. The administration of these funds was delegated to a committee of each society. During his lifetime Mr. Freeman guided the selection of scholars and the purpose for which the income of the funds should be spent.

The principles established by Mr. Freeman for the use of the income of these funds provided that a scholarship should be awarded once in three years, one from each of the three societies. This plan was not always followed, especially in the earlier years of the operation of the funds. More than one scholar in three years has been appointed. The balance of the income of the funds was to be used for some purpose associated more or less closely with the science of hydraulic engineering, and this has been done to some extent.

Occasional reports were expected from the scholars, and a final report, upon the completion of the course, if there was anything to report which might be of value to the engineering profession.

It is gratifying to note that many of those who have held these scholarships have been particularly worthy of the award and that they have become prominent in their profession.

Following is a list of the Freeman scholars of the three societies to which the Freeman Funds were given, and their present occupations. A complete history of the assignments and accomplishments of most of them is not only interesting, but is an indication of the fact that the scholarships must have been of benefit to them in the performance of their varied duties. It does not, however, seem necessary to recite their activities in this article.

Freeman Scholars of the Boston Society of Civil Engineers

1927–1929. KENNETH C. REYNOLDS. Now ranks as Associate Professor of Hydraulics, Massachusetts Institute of Technology, in charge of the hydraulic research laboratory, Cambridge, Mass.

1928–1930. SAMUEL SHULITS. Assistant Engineer, United States Bureau of Reclamation, Denver, Col., translated from the German Schoklitsch's "Hydraulic Structures."

1930–1932. CLIFFORD P. KITTREDGE. Assistant Professor of Theoretical and Applied Mechanics, College of Engineering, University of Illinois, Urbana, Ill.

1932–1933. LAWRENCE DE FABRITIS. Listed without designation of occupation, at Waterbury, Conn.

1934–1937. LESLIE J. HOOPER. Instructor in Hydraulics, Worcester Polytechnic Institute, Worcester, Mass. Author of "Representative Hydraulic Laboratories in the United States and Canada," published (as Section 2) of the Journal of the Boston Society of Civil Engineers, January, 1938.

1937–1938. MARTIN A. MASON. Now in Europe on leave of absence from the United States Bureau of Standards.

Freeman Scholars of the American Society of Mechanical Engineers *

1927. BLAKE R. VANLEER. Teaching.

1928. HERBERT H. EATON. Now in charge of the hydraulic laboratory at the United States Bureau of Standards.

1932. G. ROSS LORD. Teaching in Canada.

1933. HUGH J. CASEY. Has been in local charge of studies and of government undertakings in the line of hydraulic engineering, located at Providence, R. I.

1935. VICTOR L. STREETER. Returned to the Department of Reclamation, Denver, Col.

Mr. Davies has written, in part, as follows:

"In thinking of the effectiveness of the Freeman Scholarships, I have asked myself two questions: the first and most important is, has the individual Freeman scholar broadened in hydraulics and in other attributes which will increase his capacity for leadership? Second, did the sending of the Freeman scholars in hydraulics result in increased attention by American engineers to the need for better hydraulic research?

"To review broadly, my conclusion about the first question is definitely affirmative. As I look at the list of scholars, it seems to me that several of them have attained positions of real leadership.

"Of course the scholars were carefully selected and the general probability of having leadership developed was high.

"I believe the answer to the second question is affirmative, aided, no doubt, by Mr. Freeman's zeal and vigorous personality and his other activities, such as publication of the book on 'Hydraulic Laboratory Practice.'"

Freeman Scholars of the American Society of Civil Engineers †

DR. LORENZ G. STRAUB is now Professor of Hydraulics and Administrative Assistant in the College of Engineering and Architecture of the University of Minnesota.

F. THEODORE MAVIS is Professor and head of the Department of Mechanics and Hydraulics at the University of Illinois.

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* Names furnished by Mr. C. E. Davies, Secretary of the American Society of Mechanical Engineers.

† Names furnished by Mr. George T. Seabury, Secretary of the American Society of Civil Engineers.

Morrough P. O'Brien is Professor of Mechanical Engineering and head of the Hydraulic Laboratory at the University of California.

Clarence E. Bardsley is Professor of Hydraulic Engineering at the Missouri School of Mines, Rolla, Mo.

James B. Woodburn is Professor of Hydraulic Engineering at the University of Wisconsin.

Hans Kramer obtained the degree of Doctor of Engineering during his appointment by the Society in Europe. Since his return he has been engaged in hydraulic work with the War Department, and has been advanced to the rank of Captain.

Herbert H. Wheaton, since his return, has been teaching at the Fresno State College, Fresno, Cal.

Donald P. Barnes is in the employ of the United States Bureau of Reclamation as Associate Engineer. He has recently been interested in supplying the Society with translations of foreign papers on hydraulics.

Paul W. Thompson served at the Vicksburg Laboratory and is now in charge of the United States Water-Ways Experiment Station as Director.

Dr. John Hedberg is Assistant Professor of Civil Engineering, Stanford University, Cal.

Mr. Seabury has written as follows:

"I feel that the experience derived by the Freeman Scholars from their European trips has been most helpful to the profession. In general, it seems that they have been connected with almost all of the new hydraulic advancements.

"I am confident this has worked out well. It is my impression, also, that Mr. Freeman himself was quite happy at the outcome so long as he could view it personally. You, of course, know that he was in close touch with very many of the students, and that upon a number of occasions he even extended the appointments or enlarged their scope. I feel that he would not have put increasing funds into this activity unless he had felt that the expenditures were warranted.

"Frequently he had conferences with the appointees, particularly before and after their year abroad. In addition, he was much interested in the monthly reports which they submitted. It was our custom to transmit each of these reports not only to him but to the committee in charge. In writing, the Freeman Scholars would usually give a running account of their month's work and sometimes of their plans for the future. In addition, certain personal items would be included and very frequently a discussion of technical features of hydraulics. In some instances they would recount research work in hydraulics that they had undertaken. Very often photographs and diagrams would be incorporated in the report. In this way Mr. Freeman and also the committee could keep a more or less continuous contact with the progress of these scholars.

"Some general remarks on the Freeman Scholars may be of interest. Our Society's Committee on Hydraulic Research consists of eleven members, regular and co-operating. Of these, five are Society appointees as Freeman Scholars, and two others, as I recall, had European experience under other such auspices. I think its choice of these young men with European training is a sincere compliment to the value of the training.

"Summing it all up, I should say that these young men have made a very definite contribution in their fields. A great deal of worth-while work has been done by them and much is now under way. I believe that a major influence on the future development of hydraulic engineering in this country will be due to them."

Mr. Freeman's son, Clarke Freeman of Providence, R. I., has followed the subsequent work of many of these scholars. With reference to them he has written: —

". . . I do feel that the results obtained from the scholars whose history I know personally . . . have been even more than perhaps my father anticipated.

"Most of the real flood control problems which are being studied today are under the direction of former Freeman scholars, and some of the best hydraulic courses in the various nationally known universities have Freeman scholars as professors in charge of them.

"In the National Bureau of Standards Hydraulic Laboratory Bulletin, Series A, Bulletin 6, published January 1, 1938, I think you will find my statement well justified.

"This publication lists the experiments now in process at the important hydraulic laboratories and shows that a great deal of this work is being done by, or is under the supervision of, former Freeman scholars."

From all the information I have obtained regarding the Freeman scholars and from my personal knowledge of the accomplishments of some of them, I am convinced that as a rule they have made excellent use of the experience gained by the scholarship, and that the hopes of Mr. Freeman have been realized.

BOOKS DONATED TO THE LIBRARY OF THE BOSTON SOCIETY OF CIVIL ENGINEERS

The Library Committee has reported the receipt of the following books as gifts to the Library of the Boston Society of Civil Engineers since the Annual Meeting:

"Manual of Structural Planning and Design," by George E. Strehan and F. R. MacLeay. Gift of Arthur D. Weston.

"Special Report of the Metropolitan District Water Supply Commission and the Department of Public Health Relative to Improvements in Distribution and to Adequate Prevention of Pollution of Sources of Water Supply of the Metropolitan District, December 1, 1937." Gift of Karl R. Kennison.

"Elements of Water Supply Engineering," by Earle L. Waterman. Gift of the author.

"Structural Design," by Hale Sutherland and Harry L. Bowman. Gift of the authors.

"Structural Aluminum Handbook." Gift of Aluminum Company of America.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

SEPTEMBER 28, 1938. — A regular meeting of the Boston Society of Civil Engineers was held this evening at the Engineers Club. The meeting was called to order by the President, Karl R. Kennison. Seventy-eight members and guests were present. Fifty-two persons attended the dinner preceding the meeting.

The President announced the deaths of the following members: Thomas F. Campbell, who died April 30, 1938, and had been a member since January 22, 1908; Charles E. Houghton, who died August 29, 1938, and had been a member since June 20, 1888; Leonard C. Robinson, who died August 14, 1938, and had been a member since January 23, 1907; John H. Van Valkenburgh, who died August 3, 1938, and had been a member since March 16, 1904.

Announcement was made of the election of the following on September 28, 1938:

Grade of Member: Charles W. Crouch, Harold G. Hersey.*

Grade of Junior: Richard G. Bergstrom,† Daniel J. Putzel.†

The President called attention to the fact that this Society had been represented by delegates at two particularly interesting events: one, the dedication of the Benjamin Franklin Memorial at the Franklin Institute, Philadelphia, on May 19, 1938, when the Society was represented by Mr. Laurence B. Manley, member, of Philadelphia; and the other, the International Engineering Congress, held at Glasgow, Scotland, June 21 to 24, 1938, at which Mr. Frank S. Badger of East Horsely, England, was requested to serve as delegate, representing the Society.

The President introduced the speaker of the evening, James H. Stratton, Captain, Corps of Engineers, United States War Department, who gave a particularly interesting talk on "The Engineering Features of the Conchas Dam Project." The talk was illustrated with lantern slides. A question period followed the talk.

The meeting adjourned at 8.30 P.M.

EVERETT N. HUTCHINS, *Secretary*.

Designers Section

MAY 11, 1938. — The regular meeting of the Designers Section was held this evening at the Society Rooms.

The minutes of the previous meeting were read and approved.

Mr. J. Stuart Crandall of the Crandall Engineering Company spoke on "An Engineer's Impression of the Caribbean."

Mr. Crandall described a trip which he made in February, partly by airplane, during which he observed pier and breakwater construction at a number of places, mostly in Venezuela and Colombia.

He spoke in particular of the largest oil refinery in the world, — that on the Dutch Island of Queba, operated by the Lago Oil and Transport Company, a subsidiary of the Standard Oil Company of New Jersey; and of one nearly as large, on the island of Curacao, owned by Shell Oil.

He described the oil wells under the salt water of Lake Maracaibo, the difficulties of navigating the channel over the Maracaibo Bar, and the proposed breakwater to improve this channel. Other proposed breakwaters — that to enlarge the port at La Guaira, and that at the mouth of the Magdalena River, near Barranquilla — were also described.

Mr. Crandall described also the concrete pier at Lagunillas, on Lake Maracaibo, and one at Turiano, where General Gomez started to create a port, now discarded.

Mr. Crandall showed many pictures and slides of the places visited.

The attendance was 37, and the meeting adjourned at about 7.30 P.M.

KIMBALL R. GARLAND, *Clerk*.

APPLICATIONS FOR MEMBERSHIP

[October 15, 1938]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of fifteen (15) days from the date given.

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* Transfer from grade of Junior.

† Transfer from grade of Student.

For Admission

Avellino, Michael A., Roslindale, Mass. (b. August 29, 1910, Boston, Mass.). Graduated from East Boston High School June, 1934; attended Franklin Union, taking Lowell Preparatory Course in 1933, including surveying, field practice course; in 1936–37, took course in railroad field and office practice; and a one year course in building construction, receiving certificate. Experience: September, 1930, with Anzilli Construction Company, supervising building (drafting and estimating) garages, driveways and small homes; 1933, with Tomasello & Son, on roads, pipe lines, excavating and general heavy construction; 1935 to date, at Charlestown Navy Yard as instrumentman, chief of party, and field inspector; now supervising engineer on field work in building of pipe shop; engaged, also, on work of construction of roads, five buildings, million-dollar concrete pier, including boring and pile inspection (concrete and wood), tennis courts, track layouts, sewerage, etc. In office, plotting from field notes and computations. Refers to *L. M. Clark, S. L. Connor, J. H. Harding, R. S. Slayter.*

D'Amato, Constantine James, Milton, Mass. (b. January 31, 1904, Yonkers, N. Y.). Graduated from Yonkers Grammar and High Schools June, 1919, and June, 1923, respectively. New York University: graduated, 1927, with B.S. in Civil Engineering; 1933, with M.S. in Civil Engineering. Experience: Roma Construction Company, Yonkers, N. Y., September, 1927, to October, 1928, general superintendent; October, 1928, to February, 1931, field engineer, with Putnam County Planning Commission, Carmel, N. Y.; March, 1931, to February, 1932, resident engineer, Taconic State Park Commission, Poughkeepsie, N. Y.; March, 1932, to October, 1932, engineering superintendent, with Samuel Nugent Company, New York City; October, 1932, to March, 1933, engineer, Shrub Oak-Mohegan Water District, Shrub Oak, N. Y.; May, 1933, to November, 1933, engineer superintendent, DeChristopher Brothers, Peekskill, N. Y.; October, 1934, to February, 1936, chief of party, Westchester County Park Commission, White Plains, N. Y.; February, 1936, to March, 1936, junior engineer, Inspection Division, P. W. A., Washington, D. C.; March, 1936, to date, assistant highway engineer, United States Bureau of Public Roads, Boston, Mass. Refers to *A. B. Appleton, R. W. Coburn, G. H. Delano, G. E. Harkness.*

Odell, Edward Everett, Braintree, Mass. (b. February 16, 1914, Atlantic, Mass.). Graduated from Hollis Grammar School, Braintree, Mass., June, 1928; Braintree High School, June, 1932; Brown University, Providence, R. I., June, 1938; Rhode Island School of Design, 1938. Experience: July to September, 1935, superintendent of construction, with Samuel Glaser, architect; July to September, 1936, foreman, with Coleman Brothers Corporation; June to September, 1937, superintendent of construction, with John Deveney Company; October, 1937, to June, 1938, structural engineer, with Marshall B. Martin, architect; July, 1938, to date, engineer, with Carilli Construction Company, Boston. Refers to *Edwin F. Allbright, H. S. Cleverdon, W. F. Pike, R. M. Soule.*

Paxton, William Charles, Jr., Lexington, Mass. (b. August 31, 1909, Boston, Mass.). Graduated from Northeastern University, 1930, with degree of B.S. in Civil Engineering. Experience: Town of Lexington (Mass.), 1930–32, chief of party in engineering department; 1932–34, assistant superintendent in highway department; and 1934 to date, superintendent of highway department. Refers to *H. B. Alvord, C. O. Baird, Jr., A. E. Everett, Jr., E. A. Gramstorff.*

For Transfer from Grade of Junior

Anderson, Charles M., Somerville, Mass. (b. August 18, 1908, Roxbury, Mass.). Graduated from Northeastern University, degree of B.S. in Civil Engineering, in 1930; during co-operative periods at Northeastern University was employed as rodman and transitman, with Aspinwall & Lincoln; since December, 1929 (with exception of two school periods just before graduation), has been with Massachusetts Land Court, as assistant in engineering department, now junior engineer. Refers to *H. B. Alvord, C. O. Baird, Jr., L. A. Chase, C. B. Humphrey, L. T. Schofield.*

BEIGBEDER, PAUL ALFRED, Davenport, Iowa (b. January 27, 1910, Pau, France). Graduated from Northeastern University, degree of Bachelor of Chemical Engineering, 1932; and degree of Bachelor of Science in Chemical Engineering in 1935; July, 1932, to May, 1933, general foreman of small construction, landscaping and designing, with George Willis, architect, Thomasville, Ga.; 1933 and 1934, with C. W. A.; E. R. A. draftsman, Department of Assessors and City Planning Board, Boston, Mass.; 1934 and 1935, with Boston City Planning Board, as chief of party, W. P. A. projects; 1936–37, dredging inspector, War Department, United States Engineer Department, Boston and Buzzards Bay, Mass.; 1938 (two months), with Boston Elevated Railroad, rodman, on construction of Everett repair shop; and one and one half months, War Department, Construction Quartermaster, Fort Devens, Mass., as assistant engineer. At present, with United States Engineering Division, War Department, Clock Tower Building, Rock Island, Illinois. Refers to *H. B. Alford, E. A. Gramstorff, A. L. Guild, A. A. Minichiello.*

PILLSBURY, GERALD THEODORE, West Scarboro, Maine (b. October 27, 1910, North-Scarboro, Maine). Graduated Northeastern University, with degree of B.S. in Civil Engineering, in 1932; during co-operative periods at Northeastern University, 1930–31, rodman and transitman, with Gleason Engineering Corporation, Wellesley, Mass.; September, 1934, to January, 1935, engineer, with Sanders Engineering Company, Portland, Maine; October, 1935, to March, 1937, chief engineer, Brooklawn Memorial Park (Portland); and to date, chief engineer and superintendent. Has had engineering office in Portland since November, 1936. Refers to *H. B. Alvord, C. O. Baird, Jr., C. S. Ell, A. E. Everett, Jr., E. A. Gramstorff.*

REDFIELD, WILLIAM A., Middletown, N. Y. (b. March 4, 1910, High View, N. Y.). Graduated from Middletown High School, 1929; attended Rutgers University, civil engineering, 1929–31; transferred to Northeastern University December, 1931; graduated June, 1936, with degree of B.S. in Civil Engineering — several times on Dean's honor list. Experience: July to November, 1936, with North-Eastern Construction Company, Winston-Salem, N. C., at Roanoke, Va., on construction of Veterans Administration Facility, as field engineer on lines, grades, estimates, drafting, computations; November, 1936, to July, 1937, with White Construction Company of New York City, at Northport, N. Y., on construction of Veterans Facility, as field engineer on lines, grades, layout, inspection, estimates, drafting, computations, quantities; July, 1937, to April, 1938, at Brooklyn, N. Y., with White Construction Company, on construction of Williamsburgh Power Plant Extension, as chief field engineer, timekeeper, assistant superintendent of lines and grades, layout, estimates, inspection, supervision, drafting, computations, quantities and reports; April, 1938, to date, with A. L. Hartridge Company, New York City, at New York World's Fair (1939) on construction of exhibits for Johns-Manville, Consolidated Edison, Glass Incorporated, General Electric, Electric Utilities, Electrified Farm, American Radiator Company; from field engineer was given full charge of all field engineering and layout; now construction superintendent for Electric Utilities Exhibit Building. Refers to *H. B. Alvord, C. O. Baird, Jr., A. E. Everett, Jr., E. A. Gramstorff.*

VENTI, FRANK, East Boston, Mass. (b. October 4, 1909, Boston, Mass.). Graduate of East Boston High School. Two years at Franklin Union evening school; studied applied science and mathematics, 1927–29; completed building course, Lowell Institute. Experience: 1930–34, with Sewerage Division, Metropolitan District Commission; 1934–38, with V. Barletta Company, contractor, as engineer on bridge, sewers, air tunnels and miscellaneous structures. Now engineer for V. Barletta Company, contractor. Refers to *R. W. Loud, F. A. Marston, J. M. McNulty, Dean Peabody, Jr.*

For Transfer from Grade of Student

Campbell, Henry, Stoneham, Mass. (b. May 28, 1915, South Boston, Mass.). Graduated from Northeastern University, 1938, with honor degree of B.S. in Civil Engineering; during co-operative periods at Northeastern University was employed by city of Boston, assessors office, October, 1935, and in December, 1935, tracing, drafting and calculation of areas; July to August, 1937, Northeastern University maintenance department, reconditioning athletic field; November, 1937, to January, 1938, and since April, 1938, has been employed as assistant engineer, Public Works Department, Stoneham, Mass., on surveys and layouts, and construction and office work. Refers to *H. B. Alvord, C. O. Baird, Jr., A. E. Everett, Jr., E. A. Gramstorff.*

De Luccia, Charles Augustus, Everett, Mass. (b. August 30, 1912, Everett, Mass.). Was graduated from Northeastern University, 1938, with degree of B.S. in Civil Engineering. Experience: February to April, 1937, and February to April, 1938, with New England Survey Service as rodman and photographer; September to November, 1937, assistant to town engineer, Stoneham, Mass., as rodman and transitman on drainage, roadway and sidewalk construction projects; September, 1938, to present time, with Metropolitan District Water Supply Commission as junior engineering aid. Refers to *H. B. Alvord, C. O. Baird, Jr., A. E. Everett, Jr., E. A. Gramstorff, M. J. Markham.*

Garland, Chesley Fisher, Belmont, Mass. (b. April 14, 1916, Cambridge, Mass.). Graduated from Northeastern University, 1938, with degree of B.S. in Civil Engineering, with honor, and received Desmond FitzGerald Scholarship in 1938; during co-operative periods at Northeastern University, with Joseph Selwyn, surveyor, Belmont, Mass.; June to September, 1934, as rodman and transitman; September, 1934, to June, 1935, with Northeastern University as student assistant in the mechanical drawing and descriptive geometry departments; June, 1936, to September, 1937, with Barnes & Beal, Civil Engineers, Newton and Waltham, as draftsman, rodman, transitman and chief of party; December, 1937, to September, 1938, with Commonwealth of Massachusetts, engineering department, Land Court, as engineering assistant; September, 1938, to date, student in sanitary engineering department, Harvard Graduate School of Engineering. Refers to *H. B. Alvord, C. O. Baird, Jr., A. E. Everett, Jr., E. A. Gramstorff.*

Lewis, Robert Henry, Belmont, Mass. (b. February 16, 1915, Arlington, Mass.). Graduated from Northeastern University, degree of B.S. in Civil Engineering, in 1938. During co-operative periods at Northeastern University was rodman, with F. A. Joyce, Belmont, Mass., in 1936; from 1936 to graduation, worked with New York, New Haven & Hartford Railroad as rodman and chainman; since graduation has been with the maintenance department of the Boston Division of the New York, New Haven & Hartford Railroad. Refers to *H. B. Alvord, C. O. Baird, Jr., A. E. Everett, Jr., C. F. Garland, E. A. Gramstorff.*

Moran, Frederick P., Newton, Mass. (b. November 27, 1912, West Newton, Mass.). Graduated from Northeastern University, degree of B.S. in Civil Engineering; since graduation, with Spaulding-Moss Company, detail and drafting along with commercial art. Refers to *H. B. Alvord, C. O. Baird, Jr., W. A. Grady, E. A. Gramstorff.*

Packard, Darel O., New York, N. Y. (b. March 27, 1911, Hull, Mass.). Graduated from Northeastern University, with degree of B.S. in Civil Engineering, 1936. Experience: September, 1936, with the Semet-Solvay Engineering Corporation, New York, N. Y., as clerk in Owosso, Mich., shop; January, 1937, worked on layout and assembly; March, 1937, transferred to New York office in charge of reproduction department; and October, 1937, to date, in drafting room as a tracer. Refers to *H. B. Alvord, C. O. Baird, Jr., C. S. Ell, A. E. Everett, Jr., E. A. Gramstorff.*

Ross, John Stuart, West Roxbury, Mass. (b. July 18, 1912, Roslindale, Mass.). Prepared for Massachusetts Technology at Hyde Park High School, 1926–30; postgraduate course, 1931; graduated from Northeastern University, 1936, with degree of B.S. in Civil Engineering. Experience: May, 1937, to January, 1938, draftsman with General Electric Company, River Works, Lynn, Mass.; January to May, 1938, assistant to engineer at the Harvard Club, Boston; May, 1938, to present time, with Boston Elevated Railway Company, engineering department, on construction. Refers to *C. O. Baird, Jr., C. S. Ell, A. E. Everett, Jr., E. J. O'Conner, W. C. Pitts.*

ADDITIONS

Members

Joseph P. F. Cavazzoni, 420 Memorial Drive, Cambridge, Mass.
C. Wayland Crouch, 36 High Street, Gardner, Mass.
William H. Fitzgerald, 47 Union Park, Boston, Mass.
James A. McCarthy, 126 Atlantic Street, Quincy, Mass.

Students

John L. Bean, 131 Washington Street, Ayer, Mass.
Anthony R. Benedetto, 9 Brook Avenue, Wakefield, Mass.
Ralph S. Carr, Jr., 86 Gainsboro Street, Boston, Mass.
Alfred C. Carosi, 14 Grafton Street, Quincy, Mass.
Joseph J. Cegelski, 17 Daggett Street, New Haven, Conn.
Ralph F. Crowther, Jr., 19 Webster Street, Framingham, Mass.
Dean Freeman, 98 Porter Street, Somerville, Mass.
Winfield B. Knight, 6 Everett Street, Taunton, Mass.
Saul Landman, 98 Lawrence Avenue, Dorchester, Mass.
Frank J. Lariviere, 268 Cartier Street, Manchester, N. H.
Louis G. Reiniger, 47 Denver Street, Saugus, Mass.
Henry G. Seeley, 438 East Eighth Street, South Boston, Mass.
Louis H. Sinofsky, 9 Ottawa Street, Roxbury, Mass.
Walter E. Stone, 125 Hemenway Street, Boston, Mass.
Richard D. Sutliff, 316 Huntington Avenue, Boston, Mass.
L. Gerard Wahl, 328 Lynn Street, Malden, Mass.

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Thomas F. Campbell .	Apr. 30, 1938
Charles E. Houghton .	Aug. 29, 1938
Leonard C. Robinson .	Aug. 14, 1938
John Van Valkenburgh	Aug. 3, 1938

BOOK REVIEWS

*"Structural Design," June, 1938, by Hale Sutherland and Harry L. Bowman. John Wiley & Sons, Inc., New York. 397 pages. Price, $4.50.**

This companion volume to the authors' book, "Structural Theory," deals chiefly with the application of the theory of structures and of test results to the solution of practical design problems. While planned as a textbook in an unusually clear and convincing style, the well-balanced theoretical and practical treatment should make it serviceable to the practicing designer.

The book is also well suited for self study. The authors' experience of many years in teaching has given them an understanding of the mental habits of students. Difficulties and possible sources of error are anticipated, and occasional comments of advice serve to aid the reader. Frequently the reader is halted by a searching question thrown at him. This makes him stop to think in much the same way that a student's mental activity is aroused when questioned by his instructor to test if he has grasped the subject.

Practice problems are followed by answers or by suggestions for a solution. This does not detract from the independent thinking required for their solution. It is an indication that care was given to the selection of problems.

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* By Eugene Mirabelli, Associate Professor of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

The reviewer was impressed by the first chapter which deals with beam theory. The chapter title might suggest a review of elementary theory. However, there are included such subjects as the general or unsymmetrical case of flexure (as contrasted with the common beam theory), the use of the S-line or S-polygon, torsion in beams, principal stresses in webs and buckling. One who can absorb the contents of this chapter will get an improved understanding of beam action. Even if this theory is not used in design computations, it supplies the background necessary for making intelligent assumptions and approximations in rapid design. Much of this chapter is in small print, and the authors apparently do not intend that it be used in an elementary course.

The other introductory chapters deal with column theory, giving a chronological development of column formulas, with riveted connections and plate girder theory.

Then follow chapters on design of girder and truss railway and highway bridges, mill buildings, office building frames and timber roof trusses, and a chapter on structural welding.

The illustrative design problems deal chiefly with steel structures, and are shown on design sheets (each sheet is a full page of the book) with computations lettered and arranged in the same manner that design computations are arranged in an engineering office. This makes a clear and concise presentation. Explanatory comments on the contents of the design sheets appear in the text.

The appendix is unusually long, comprising about 25 per cent of the entire contents of the book, and contains several of the more recent specifications. There are a number of folding plates showing detail or general drawings for the illustrative design problems.

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*"Elements of Water Supply Engineering," by Earle L. Waterman, Second Edition, 1938. John Wiley & Sons, Inc., New York. 329 pages. Price, $3.50.**

This book has been planned as a textbook for a short introductory course in water supply engineering for civil engineering students. The original text has been expanded in the second edition to include a description of the Hardy Cross method of flow analysis in pipe networks; a short description of the Proctor method of earth dam design; new material on mixer and clarifier equipment; a section on tastes and odors; and problems. The section dealing with the expression of results of the coli tests in the bacteriological examination has been revised to include procedure in computation of the "most probable number" as given in the eighth edition of "Standard Methods of Water Analysis."

Students will find this book of value in introducing them to the field of the waterworks engineer. The treatment is too elementary for the use of advanced students or engineers engaged in design.

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* By Thomas R. Camp, Associate Professor of Sanitary Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

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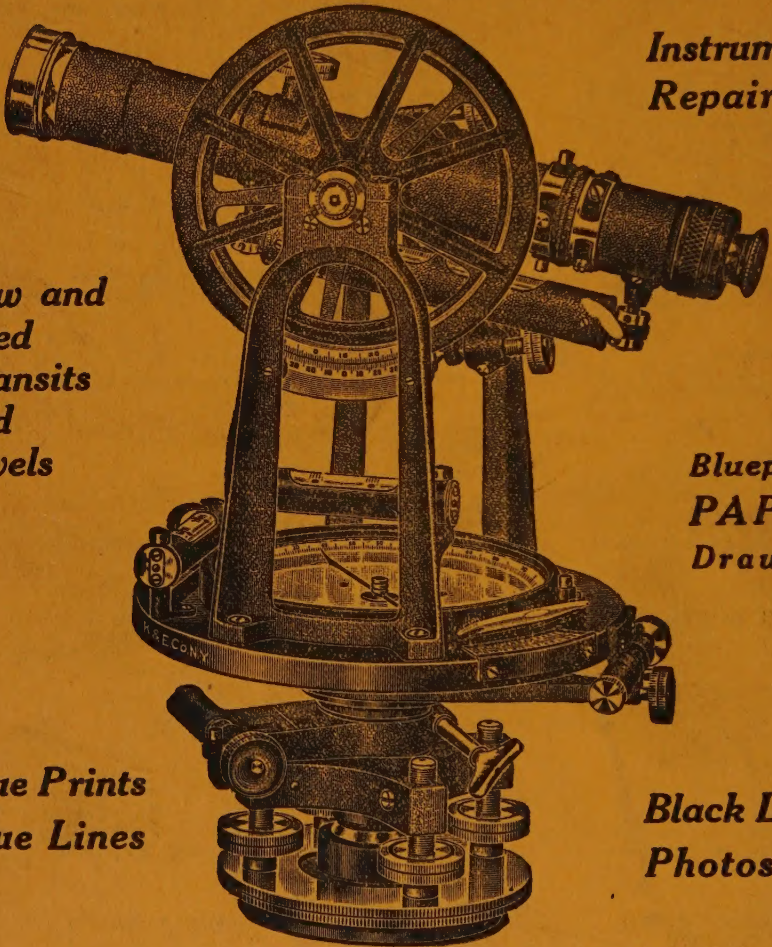

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